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NUCLEAR ALIBI: THE NUCLEAR REVIVAL AND PROLIFERATION

By

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Abstract

This thesis looks to answer a two-part question. First, are states aspiring to nuclear energy for the first time as a part of the purported nuclear revival doing so with the intention of acquiring a latent nuclear weapons capability? And second, does the nuclear revival as a consequence have a high risk of nuclear weapons proliferation? To do so it will analyze the drivers of and barriers to new nuclear energy programs, apply major theories of proliferation and explore the technical connection between nuclear energy and weapons. It will then apply those understandings to a global survey of aspiring nuclear energy states in order to identify and further examine states that appear particularly predisposed towards being motivated by a desire for nuclear weapons. By doing so, this research can contribute to our understanding of the connection between nuclear energy and nuclear weapons, and provide a balanced assessment of some of the possible security implications of the spread of nuclear energy.

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Introduction

This thesis will attempt to determine if states aspiring to nuclear energy as a part of the purported nuclear revival are doing so with the intention of acquiring a latent nuclear weapons capability, and if the nuclear revival as a consequence has a high nuclear weapons proliferation risk. Recently renewed interest in nuclear energy in dozens of states without a current nuclear program raises the potential for a diffusion of nuclear technology around the globe. This renewed interest is claimed to be driven primarily by climate change, energy security, and the rising cost of fossil fuels. As one nuclear industry advocate stated, “One of the fundamental imperatives in the world is to harness the source of this cheap energy. I have no doubt we’ll have 3,000 reactors, and I’ve heard projections of 10,000.”¹ There are, however, numerous challenges to a nuclear expansion given the perhaps insurmountable barriers posed by cost and financing, physical infrastructure, nuclear safety, personnel and nuclear waste. While nuclear energy is likely to remain a useful part of the energy mix in a number of states, the expansion some observers foresee or call for is unlikely.

Nuclear energy seems an especially odd choice for the dozens of developing nations that have announced their intentions to pursue it, and there are doubts about whether the aforementioned drivers of a nuclear expansion are what are truly motivating them. These doubts have led some observers to raise alarms about a potential spread of nuclear energy, including, for example, Executive Director of the Nonproliferation Policy Education Center (NPEC) Henry Sokolski:

¹ Steven Kidd, quoted in: Tom Zoellner, “Nuclear power gets its swagger back,” *The Globe and Mail*, 14 March 2009.

*Countries can cheat on pledges not to make nuclear fuel by exploiting the International Atomic Energy Agency's (IAEA) inability to detect in time a covert nuclear fuel making plant under construction or even military diversions from one already operating. It does not make sense to share large reactor technology with any country that we cannot trust to stay out of the bomb making business. This would include many countries in the Middle East.*²

Many of the developing nations interested in nuclear power are indeed located in the Middle East, with several others in North Africa or Southeast Asia—regions with a history of instability. An article on the front page of the New York Times from 15 April 2007 was titled, “With eye on Iran, rivals also want nuclear power: Fears of an arms race,” signifying that concern of the risk was not limited to a few proliferation experts, but reached popular media outlets as well.³ An interim report from the Congressional Commission on the Strategic Posture of the United States from 2008 stated that the world could face a “cascade of proliferation” spurred on by concerns about nuclear programs in Iran and North Korea.⁴ Academic studies, such as Matthew Fuhrmann’s “Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements,” have also raised concern about a diffusion of nuclear technology.⁵ The *Bulletin of the Atomic Scientists* has featured articles with cautions about the purported revival of nuclear energy, with such titles as “Arab nuclear envy” and “A frightening legacy.”⁶ These

² Henry Sokolski, “Additional View of Commissioner Henry Sokolski,” in *World at Risk: Report of the Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism* (New York: Vintage Books, 2008).

³ “William J. Broad and David E. Sanger, “With eye on Iran, rivals also want nuclear power: Fears of an arms race,” *The New York Times*, 15 April 2007.

⁴ “World Faces ‘Cascade of Proliferation,’ Report Says,” *Global Security Newswire*, 16 December 2008, http://www.globalsecuritynewswire.org/gsn/nw_20081216_6611.php (accessed 27 September 2009).

⁵ Matthew Fuhrmann, “Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements,” *International Security* 34:1 (2009).

⁶ Sammy Salama and Heidi Weber, “Arab nuclear envy,” *Bulletin of the Atomic Scientists* (September/October 2007); Zia Mian and Alexander Glaser, “A frightening nuclear legacy,” *Bulletin of the Atomic Scientists* (September/October 2008).

examples, among others, are a clear indication that many observers are concerned about what a potential nuclear revival will contribute to nuclear weapons proliferation.

A peaceful nuclear energy program can provide a state with some of the technological capacity and expertise to produce nuclear weapons, especially a program involving the full fuel cycle, so a new nuclear energy state could mean a new state with a latent weapons capability. An expansion of nuclear energy to new states therefore enhances the potential for nuclear weapons proliferation due to what is commonly referred to as nuclear “hedging”. Hedging is the acquisition of a break-out capability for nuclear weapons obtained by building up a peaceful nuclear infrastructure that can be diverted to weapons uses. The purpose of hedging is to have the ability to develop nuclear weapons quickly should the strategic environment of a state become more threatening, with that increased threat generally considered to be a new nuclear threat. Iran’s nuclear program is the prime example of hedging although in this case Iran is doing so with a view to countering existing nuclear threats from the US and Israel. The proliferation risk of the nuclear revival stems from concerns that other states intend to emulate Iran. That potential, however, will only be realized if states are willing to disregard their legal commitments not to acquire nuclear weapons and withstand the backlash from the international community that doing so would entail.⁷ The underlying premise of this thesis is that the proliferation risk of a peaceful nuclear expansion is mainly dependent on state intention to acquire nuclear weapons rather than technical capacity to do so, although both are important. The technical difficulty in developing a nuclear weapon, the verification system of the IAEA and enforcement measures reduce the chances that a state

⁷ All states with the exceptions of India, Israel and Pakistan are party to the 1968 Nuclear Non-Proliferation Treaty (NPT) and have committed to never pursue nuclear weapons. Britain, China, France, Russia and the United States are NPT parties as well, but are designated official nuclear weapon states.

desiring nuclear weapons will ultimately acquire them, but the intention of a state to pursue nuclear weapons inherently increases proliferation risk irrespective of success or failure in acquiring them.

The justifications states have used for pursuing nuclear energy include reducing carbon emissions, energy security, rising energy demand and a belief that advanced technology leads to economic and social progress. These justifications can at times appear to be misleading or inaccurate. One possible inconsistency to be explored further is the claim from some energy-rich states with large deposits of oil and natural gas—mainly in the Middle East—that they need nuclear power to improve their energy security. Fossil fuels are, however, an unsustainable finite resource, so those claims may in fact have legitimacy. Such justifications nonetheless raise questions and have led to concerns that states may be motivated by more than the benefits they cite publically, and rather by the desire to have a nuclear weapons option. Although the odd exception cannot be ruled out, it intuitively seems unlikely that even a few states are pursuing nuclear energy to acquire a nuclear weapons option. Nuclear energy may not make economic sense for a number of states involved in the purported nuclear revival, but desires for it within those states are likely the result of poor energy policy and misguided hype over the benefits of nuclear energy rather than ulterior motives, as will be discussed in more detail later.

In assessing the proliferation risk of a nuclear expansion it is important to seek a better understanding of what leads states to pursue or reject nuclear weapons and of the complex technical relationship between nuclear energy and nuclear weapons. This research will limit its analysis to those countries that have the technical capacity to connect a peaceful nuclear energy reactor to their electrical grids by 2030 because making predictions about intent beyond then becomes too difficult. The theoretical literature about why some states

proliferate will be used to determine indicators that can be used to identify states that seem particularly prone to being motivated by a nuclear weapons option. The identified states will then be examined in more detail to reveal a potential link between their pursuit of nuclear energy and possible weapons motivations. In sum, this thesis will assess the proliferation risk of the purported revival by identifying states that appear to have both the capacity and possible intent to pursue a peaceful nuclear energy program to obtain a latent nuclear weapons capability.

The research for this project is based primarily on academic literature, government reports, news articles, energy proposals and security documents. It will draw from the Nuclear Energy Futures Project's *Survey of Emerging Nuclear Energy States* (SENES), of which the author was a contributing researcher for and now oversees.⁸ SENES is an original research product that tracks the progress of aspiring nuclear energy states in their pursuit of nuclear power. Given the qualitative nature of the question posed field work consisted of typically private meetings and discussions with over a dozen officials and experts in Australia, Austria, Canada, the UK and the US. Through various conferences and meetings organized by the Canadian Centre for Treaty Compliance (CCTC) the author has had access to many of the foremost experts in the field, including IAEA officials in Vienna, civil servants from both Foreign Affairs and Trade Canada (DFAIT) and the US Department of State, nuclear industry representatives from several organizations in Canada and abroad, and other academics and analysts. For ethical reasons the names and positions of many of these sources cannot be revealed. Their input has, however, proven invaluable in contributing to well informed and balanced research,

⁸ Nuclear Energy Futures Project, *Survey of Emerging Nuclear Energy States (SENES)*, (Waterloo: Centre for International Governance Innovation, 2009).

particularly given the security sensitivity and secrecy surrounding a threat as dangerous as nuclear proliferation.

The first half of this thesis will explore the relationship between nuclear weapons proliferation and nuclear energy. Chapter one will establish context by reviewing the drivers of and barriers to the purported nuclear revival, and by debunking unrealistic expectations of it. It will also suggest the possibility that weapons may be a motivation for nuclear energy by discussing some of the overwhelming barriers to a significant nuclear energy expansion that would intuitively dissuade most states from attempting to take the nuclear route to meet their energy demands. Chapter two will identify and analyze the major theories of proliferation. Proliferation theorists have spent decades trying to determine what motivates some states to pursue the bomb. Rather than attempting to reinvent what these theorists have already done, this thesis will apply existing theories of proliferation to the purported nuclear revival to determine how nuclear energy fits into the equation. Chapter three will answer the question of what an otherwise peaceful nuclear energy program can provide in technical terms towards nuclear weapons development. Perhaps the most revealing indicator of intent is whether or not a potential proliferating state even has the technological sophistication and expertise to pursue a nuclear weapon. As it currently stands, many of the states some observers are concerned about are not able to build a nuclear weapon even if they desired it, but a nuclear revival could potentially change that.

The second half of this thesis is devoted to answering the question of whether or not a nuclear weapons option might be motivating aspiring nuclear energy states. Chapter four will identify which aspiring nuclear energy states are most likely motivated by nuclear weapons or a weapons option. It will do so first by assessing whether or not the nuclear

energy plans of these aspiring states are feasible – many of these states are not yet at a stage in their economic development where nuclear power is a realistic energy option. Proliferation risk does not materialize if nuclear plans are unable to proceed for pragmatic reasons.⁹ It will then apply proliferation risk indicators derived from the theory literature to determine which among the remaining states warrant further analysis. Chapter five will analyze in detail the states identified in chapter four, emphasizing the existence of a convincing and logical need for nuclear energy, the role of nuclear weapons in their strategic environments, and their participation and role in the nonproliferation regime.

The purported nuclear revival has implications for the international nonproliferation regime as well as global efforts to combat climate change. While the spread of nuclear technology is potentially dangerous, nuclear energy is one possible way for states to reduce carbon emissions. To take a hard line stance against nuclear energy for whatever reason, of which proliferation may be one, is more complicated now given the challenges of climate change, energy security and rising energy demand. Policy makers, activists and academics alike have had difficulty in weighing the costs and benefits of a nuclear expansion, particularly to the less stable regions of the world. This thesis ultimately seeks to contribute to this discussion by examining in detail the one particular aspect of proliferation in a nuclear revival. There is a lacuna in the literature about nuclear energy linking state motivations for nuclear energy to theoretical understandings of why states want or reject the bomb. This research is one of few that addresses the connection between nuclear energy and nuclear weapons proliferation theory, and as far as is known the first to explore that connection in the context of the nuclear revival.

⁹ That these plans are unrealistic does not preclude the possibility that these states are motivated by nuclear weapons or a weapons option. The justification for removing these states from consideration will be elaborated in Chapter 4.

Chapter 1 – New nuclear energy: drivers and barriers

Nuclear power had its heyday in the 1970s and 1980s when several reactors were brought online each year, peaking at 32 brought online in 1985.¹⁰ Two major nuclear accidents—in 1979 at Three Mile Island in the United States and in 1986 at Chernobyl in the Ukraine—along with a drop in fossil fuel prices were enough to all but halt new nuclear build in the years that followed.¹¹ As concerns about climate change, energy security and growing electricity demand became more acute in the early 21st century, proponents of nuclear power began emphasizing its benefits to meeting these three challenges. In January 2008 the Uranium Information Centre (UIC) listed 34 reactors under construction, 93 reactors in the planning stages and 222 reactors ‘proposed’ worldwide.¹² The World Nuclear Association (WNA) lists over 40 nuclear reactors expected to be in operation by 2015 in 11 countries, with most of this construction occurring in China, Japan, Russia and South Korea.¹³ Since 2000, however, taking into account reactors that have come online and those that have been shut down, a net of two reactors have been connected to electricity grids globally.¹⁴ There is, if nothing else, certainly a lot of talk about a major expansion of nuclear energy in the coming decades.

The term “nuclear renaissance” was coined to refer to a rebirth of the nuclear industry, an industry that would be better equipped to overcome the drawbacks of nuclear energy in

¹⁰ “Power Reactor Information Service,” *International Atomic Energy Agency*, <http://www.iaea.org/programmes/a2/> (accessed 2 September 2009).

¹¹ Nuclear Energy Agency, *Nuclear Energy Outlook 2008*, (France: Organisation for Economic Cooperation and Development, 2008), 45-58.

¹² Uranium Information Centre, “World Nuclear Power Reactors 2006-2008,” 14 January 2008, <http://www.uic.com.au/reactors.htm> (accessed 19 March 2008).

¹³ “Plans for New Reactors Worldwide,” *World Nuclear Association*, <http://www.world-nuclear.org/info/inf17.html> (accessed 3 September 2009).

¹⁴ “Power Reactor Information Service.”

order to meet the energy needs of society in the 21st century. The term “renaissance”—while adding a certain allegorical appeal to nuclear energy by suggesting its rebirth—is an unfitting description for many reasons, not least of which is that the word renaissance implies a kind of progress that is not accurately reflected in the nuclear industry. Experts in the field outside of the nuclear industry have widely adopted the term “revival” as a more sober and neutral term to describe the apparent resurgence of nuclear energy.

Nuclear energy is, despite much of the hype suggesting otherwise, still widely in decline at the macro level. While new nuclear build in the coming decades seems to be a certainty, particularly as rising powers such as China and India expand their nuclear fleets, as a contributor to the world energy supply the nuclear industry will struggle immensely just to maintain the status quo. Nuclear energy as a percentage of global energy production is in fact predicted to decline rather dramatically over the coming decades. The Nuclear Energy Agency’s (NEA) projections for nuclear energy determined that without a major policy focus on expanding nuclear its share of global electricity production will fall from the current 15 percent¹⁵ to 10 percent by 2030, and 6.7 percent by 2050.¹⁶ The NEA concluded that with “business as usual, fossil fuels (coal, oil and natural gas) will provide a growing share of energy supply, while nuclear power will not make a significant contribution to meeting demand growth.”¹⁷ The Massachusetts Institute of Technology (MIT) released a 2009 update to its 2003 study on the future of nuclear power with a more pessimistic outlook. The study questioned the contribution that nuclear could make to climate change in particular without major policy support, emphasizing that since the study was released in 2003 “no new nuclear units have started

¹⁵ Down from approximately 17 percent in 2002.

¹⁶ Nuclear Energy Agency, 100.

¹⁷ Nuclear Energy Agency, 94.

construction [in the US].”¹⁸ The reasons for why nuclear is not likely to contribute much to reducing carbon emissions or meeting energy demand in the coming decades are discussed below.

The nuclear revival is still of potential proliferation concern despite its rather modest projected contribution to the global energy mix. As nuclear power spreads, so too does the possibility that states could misuse their nuclear capabilities to attempt developing a nuclear weapon. Nuclear power and nuclear weapons are inextricably linked, as discussed in chapter three. A new nuclear energy state increases the potential for nuclear weapons proliferation simply because it adds to the number of states that are technically capable of developing them.¹⁹ The risk of nuclear proliferation with respect to the nuclear revival is, however, one that is better measured by monitoring and analyzing each state as it pursues nuclear energy. Starting a new nuclear energy program is a slow process—it typically takes at least a decade—so monitoring and analyzing individual states is not as arduous a task as it may first appear, at least not over time.

The greatest concern with the nuclear revival is that dozens of states are interested in having nuclear energy, and if all of those states were to move forward at once verifying nonproliferation would become more arduous as the IAEA's already limited resources would be stretched thinner. A rapid influx of nuclear power plants to several countries would place a challenging burden on the safeguards system of the IAEA and spread more thinly the intelligence resources of concerned states. The reality, however, is that neither the global nuclear industry nor most of the states in question have the capacity to move forward quickly. There are (as of August 2009) 29 countries that have expressed interest

¹⁸ John M. Deutch et al., *Update of the MIT 2003 Future of Nuclear Power* (Boston: Massachusetts Institute of Technology, 2009), 4.

¹⁹ Chapter 3 is dedicated to exploring this subject more fully.

in nuclear power as a part of the purported nuclear revival that have not previously begun construction on a nuclear power reactor.²⁰ These states are at various stages in their pursuit of nuclear energy.²¹ These 29 countries comprise the population of this research:

Table 1 – Aspiring Nuclear Energy States

Country				
Central Asia	Albania	Kazakhstan	Mongolia	
Africa	Algeria	Ghana	Morocco	Namibia
	Nigeria	Senegal	Tunisia	
Europe	Belarus	Poland		
Middle East	Bahrain	Egypt	Jordan	Kuwait
	Libya	Oman	Qatar	Saudi Arabia
	Syria	Turkey	UAE	
South America	Venezuela			
South Asia	Bangladesh			
Southeast Asia	Indonesia	Malaysia	Thailand	Vietnam

Many of these states are located in regions known for instability, particularly North and West Africa, the Middle East and Southeast Asia. One explanation for why these states are pursuing nuclear energy is that they are hedging by acquiring a latent nuclear weapons capability. This hypothesis needs to be weighed against the other factors driving interest in nuclear energy.

²⁰ This excludes Iran, Italy and the Philippines from consideration for the purposes of this research because each began construction of a nuclear power plant prior to 2000, and therefore have a longer history of pursuing nuclear energy beyond that of the purported nuclear revival.

²¹ Nuclear Energy Futures Project.

Drivers of new nuclear energy

In order to assess why these states have decided to pursue nuclear energy it is important to understand what the purported benefits of it are. The majority of states in the international system are almost certainly not interested in it because of a surreptitious desire to acquire a nuclear weapon. Their interest in nuclear power is derived from its professed ability to resolve major energy challenges in the 21st century, particularly climate change, energy insecurity and rising energy demand. None of these drivers are mutually exclusive from acquiring a latent weapons capability, but they are an essential part of the equation in determining state motivations.

Climate change

Perhaps the greatest factor working to encourage an expanded role for nuclear energy is the potential contribution it can have towards reducing greenhouse gas emissions that are contributing to global warming. Nuclear power is the only established, nearly carbon free source of electricity currently available to produce base load power.²² Some commentators have gone as far as to say that nuclear power is the only option for reducing carbon emissions, such as James Lovelock, creator of the Gaia hypothesis, who claims, “There is at present no other safe, practical and economic substitute for the dangerous practice of burning carbon fuels [than nuclear power].”²³ Nuclear is not entirely carbon free since fossil fuels are used during the mining process, but these emissions are small and probably negligible over the forty or higher year life of the

²² Research and development is currently underway on alternatives, and in particular carbon capture and storage (CCS) technologies that may make coal fired plants a viable option in a carbon-free world.

²³ Bruno Comby, *Environmentalists for Nuclear Energy* (Paris: TNR Editions, 2001).

average nuclear power plant.²⁴ Renewable energy like wind and solar are carbon-free, but they need to be widely dispersed and are dependent on weather conditions. Nuclear is likely to at least continue to be a part of the energy mix in some regions because it can contribute towards reducing carbon emissions.

The hype regarding what nuclear can contribute to reducing carbon emissions, however, outstrips what it can actually contribute in a timely manner. The International Energy Agency (IEA) projects that in a business-as-usual scenario²⁵ global carbon emissions will reach 62 Gt by 2050 compared to 27 Gt in 2005. The IEA has two approaches for carbon reduction by 2050—the “ACT” scenarios that use existing technologies to keep carbon levels at 2005 levels by 2050 (a 35 Gt carbon reduction), and the “BLUE” scenarios that reduce carbon levels by 50 percent of 2005 levels by 2050 (a 48 Gt carbon reduction).²⁶ Both approaches include nuclear as a contributor, but only a minor one. In each approach, nuclear only accounts for a 6 percent reduction in carbon (2.1 and 2.9 Gt of carbon displaced respectively) with end use efficiency and renewable energy accounting for over half of the reduction.²⁷ Nuclear energy does have a role in working towards a carbon reduced world, but IEA projections suggest that it is not the solution to climate change that some advocates claim. Reasons for why nuclear cannot contribute more to reducing carbon emissions will be explained in more detail in the constraints section of this chapter. Studies of the future of nuclear power—such as the Nuclear Energy Agency’s (NEA) *Nuclear Energy Outlook 2008* or the Massachusetts Institute of Technology’s (MIT) *The Future of Nuclear Power*—profess the need for

²⁴ International Energy Agency, *Energy Technology Perspectives 2008*, (Paris: Organisation for Economic Co-Operation and Development, 2008), 284-286.

²⁵ A business as usual scenario means no new energy and climate policies will be introduced to limit carbon. These policies would include measures such as a carbon tax or a cap-and-trade system.

²⁶ International Energy Agency, *Energy Technology Perspectives 2008*: 63-68.

²⁷ International Energy Agency, *Energy Technology Perspectives 2008*: 63-68.

governments to devote resources towards a rebirth of the nuclear industry so that it can make a useful contribution towards reducing climate change.²⁸ Government efforts to promote nuclear are, however, only sensible if they are a part of broader energy strategies that include provisions to improve end use efficiency and renewable energy technologies given their greater potential—according to the IEA—for reducing carbon emissions.

Interest in nuclear power to reduce carbon is nonetheless evident in a number of states. The best example of climate change concerns driving interest in nuclear power is probably the United Kingdom. A 2007 White Paper concluded that “New nuclear power stations could make a significant contribution towards tackling climate change.”²⁹ While a similar White Paper in 2003 was sceptical about the nuclear option, the British government reached the conclusion in 2007 that, “Giving energy companies the option of investing in new nuclear power stations lowers the costs and risks associated with achieving our energy goals to tackle climate change and ensure energy security.”³⁰ The British government is letting the market decide if new investment in nuclear will proceed, but it has nonetheless endorsed it as a way to combat climate change. Climate change is also a factor—though typically not the main driver—among aspiring nuclear energy states as well. One example is UAE Foreign Minister Shaikh Abdullah’s public statements that despite the country’s fossil fuels nuclear can contribute towards offsetting carbon emissions in the UAE.³¹

²⁸ Nuclear Energy Agency: 417-419; John M. Deutch et al., *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Boston: Massachusetts Institute of Technology, 2003): 8, 10-11, 13, 16.

²⁹ *Meeting the Energy Challenge: A White Paper on Energy* (London: HM Government, 2007): 189.

³⁰ *Meeting the Energy Challenge: A White Paper on Energy*, 195.

³¹ “UAE to set up Emirates Nuclear Energy Corporation,” *Gulf News*, 21 April 2008, <http://www.gulfnews.com/Nation/Government/10207145.html> (accessed 3 September 2009).

The problem with using nuclear to offset carbon emissions is that it is not likely able to do so quickly enough. The greatest challenge that nuclear power faces is that the time it takes to go from initial planning for a new nuclear plant to its connection to the grid are typically long, often more than a decade. The most recent example—the AREVA Olkiluoto-3 reactor in Finland—is now projected to have a 72 month construction time, two years longer than the initial timeline called for.³² Although predictions for when it is too late to mitigate the effects of climate change vary, there is growing consensus that it is becoming increasingly urgent that steps are taken in the short term to begin cutting carbon emissions immediately.³³ The 2009 update to MIT’s nuclear energy study—a study intended to find ways of improving nuclear energy’s capacity to reduce carbon—cautioned that, “the sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation.”³⁴ Nuclear energy seems likely to be only a modest contributor to global carbon reduction.

Energy security

Another often cited driver of the purported nuclear revival is that nuclear power enhances energy security by diversifying energy portfolios and reducing dependence on fossil fuels. Statements about nuclear power and energy security are especially common in the United States, such as Senator John McCain’s 2008 claim that, “Civilian nuclear power provides a way for the United States and other responsible countries to achieve

³² International Energy Agency, *Energy Technology Perspectives 2008*: 286-287.

³³ Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report*, (Geneva: World Meteorological Association, 2007).

³⁴ Deutch et al., *Update of the 2003 MIT Future of Nuclear Power*, 4.

energy independence and reduce our dependence on foreign oil and gas.”³⁵ Aspiring nuclear energy states often declare that energy security is motivating them to pursue nuclear energy. Head of the Jordanian Atomic Energy Commission, Khaled Toukan said that, for example, “Jordan imports 96 percent of its energy needs, with no long-term option to deal with energy security and future supply and price volatility...As a result, Jordan has been seriously exploring nuclear power as a viable long-term alternative for electricity generation.”³⁶ These statements that nuclear power can improve energy security are common among the aspiring nuclear energy states.

The energy security argument for nuclear power is certainly a valid one to make, but it also needs to be qualified to be fully understood. Nuclear power is only useful for electricity production, which only accounts for a portion of total energy use. It is therefore only useful to offset the small portion of a state’s oil dependence that is used for electricity generation. Oil is not widely used for electricity generation—except in the Middle East³⁷—because it is expensive and is needed for industry, transportation and residential and commercial heating.³⁸ The IEA has predicted that oil will decline from producing its current 7 percent of electricity to about 3 percent by 2030.³⁹ If electric cars make substantial headway in replacing gas-powered cars then nuclear generated electricity can indeed assist to offset dependence on oil. However, much in the same way that nuclear was only one small part of the equation in reducing carbon, it would likewise only be one part of increasing electricity output. The contribution that nuclear can make

³⁵ Sharon Squassoni, *Nuclear Energy: Rebirth or Resuscitation?* (Washington DC: Carnegie Endowment for International Peace, 2009), 5.

³⁶ Khalid Neimat, “Officials see Kingdom exporting electricity within 10 years,” *The Jordan Times* 9 June 2009, <http://www.jordantimes.com/?news=17390> (accessed 3 September 2009).

³⁷ British Petroleum Company, *BP Statistical Review of World Energy 2009*, (London: British Petroleum Company, 2009).

³⁸ Squassoni, 5.

³⁹ Squassoni, 5.

to reducing states' dependence on oil is dependent on how much a given state relies on oil for electricity production.

Nuclear energy is also not a fully “independent” source of electricity, debunking some claims—such as that of John McCain quoted above—that nuclear is a step towards “energy independence”. The nuclear industry is dominated by a select few existing suppliers of fuel and reactor technology. While uranium deposits exist everywhere at various ore grades, three countries—Canada, Australia and Kazakhstan—currently mine nearly 60 percent of the world’s uranium.⁴⁰ Uranium conversion, enrichment, fuel fabrication and reprocessing (in theory if not in practice) technologies are available in only a few states⁴¹, although those states have so far been able to fully meet demand.⁴² There are furthermore only a handful of companies that design and build nuclear reactors, originating primarily from Canada, France, Japan, Russia and the US.⁴³ As one commentator describes it, “new entrants into the nuclear energy field might be pursuing energy independence, but they will wind up with energy interdependence.”⁴⁴ It is entirely fair to say that nuclear power can enhance energy security, but that it is a step towards energy independence is a myth.

Nuclear aspirations justified on the basis of improving energy security are generally valid for two reasons. First, acquiring a diversity of energy sources of which nuclear may be one is a logical choice. A state with a diversified energy portfolio is less vulnerable to fluctuations in price or supply of any one particular type of fuel. It can be risky to depend

⁴⁰ World Nuclear Association, “World Uranium Mining,” <http://www.world-nuclear.org/info/default.aspx?id=430&terms=uranium+production> (accessed 13 June 2009).

⁴¹ There are 10 countries with a conversion capability, 9 with enrichment, 18 with fuel fabrication and 3 with reprocessing. For a complete listing see: Nuclear Energy Agency, 57.

⁴² Nuclear Energy Agency, 160-161.

⁴³ Nuclear Energy Agency, 317.

⁴⁴ Squassoni, 13.

on too few sources for energy needs, particularly if those sources are not indigenous. States are therefore perfectly justified in wanting nuclear energy to improve their overall energy portfolios. Second, some states do in fact depend on fossil fuels for their electricity generation as well as for the other end uses previously listed. In the Middle East, 98 percent of energy consumption—including electricity—is of oil and natural gas.⁴⁵ It is likely not a coincidence that there are currently 12 states in the region interested in nuclear energy. The region is oil rich, explaining the use of fossil fuels for electricity generation, but by reducing the amount of oil consumed domestically, Middle Eastern states can reserve more oil for export while reducing the risk posed by declining stockpiles. Nuclear energy can indeed be useful to improve energy security, as the example of Jordan's dependence on energy imports above indicates.

Rising energy demand

The most simplistic explanation for why a state would want to acquire nuclear power is in order to meet its energy demand. Energy demand is expected to increase greatly over the next fifty years, particularly in developing countries, often as a result of rapidly increasing populations. Some aspiring nuclear states already face massive electricity shortages. Bangladesh—which has been pursuing nuclear power since 1961⁴⁶—generates 3,000 MW at peak capacity, which was still 2,000 MW short of demand in 2007.⁴⁷ Forecasts of future world population vary from an increase from the current just over 6 billion people to between 7.8 and 10.8 billion by 2050.⁴⁸ As developing countries industrialize, economic growth is also expected to increase energy intensity, meaning

⁴⁵ British Petroleum Company, 41. This figure excludes Turkey.

⁴⁶ Nuclear Energy Futures Project.

⁴⁷ "Bangladesh To Build Nuclear Power Plant," *Agence France-Presse*, 24 June 2007.

⁴⁸ Canadian Energy Research Institute, *World Energy: The Past and Possible Futures*, (Calgary: Canadian Energy Research Institute, 2008), 26-27.

increases in per capita energy use in countries with currently low rates.⁴⁹ Technological advancements and concern about the environment are likely to slow rising energy demand somewhat, but nearly all scenarios of future energy demand nonetheless predict a substantial increase.⁵⁰ The International Energy Agency forecasts that under a business as usual scenario, electricity generation will increase by 179 percent from 2005 levels by 2050, from 18,196 TWh/yr to 49,934 TWh/yr. Nuclear energy is one option for meeting this increase in demand, which may explain new interest in nuclear power where there previously was none.

Prestige

Although nuclear energy is a sixty year old technology, there is still a sense of grandeur connected with it that may be motivating states to pursue it. Nuclear power is often viewed as a sign of technological and societal progress, and as such political leaders have often drawn attention to nuclear development to garner political support. There is no better example of associating nuclear power with national pride than Mahmoud Ahmadinejad, president of Iran. His appeals to the public have included relatively tame statements of entitlement, such as his 2008 statement, “We [the Iranian people] have been promised nuclear power by this time next year in our power grid.”⁵¹ On other occasions the prestige element of nuclear power is much clearer in his speeches:

Do you see how they treat our nation that, relying on the creativity of its own scientists, has been able to achieve access to nuclear technology? Whereas today, nuclear technology is one of the primary foundations for progress and serving the people; and in the not too distant future, nations lacking this technology will have no choice but to resort to it in order to

⁴⁹ Canadian Energy Research Institute, 28-36.

⁵⁰ Canadian Energy Research Institute, 28-36.

⁵¹ Nazila Fathi, “Ahmadinejad sees nuclear energy in Iran by 2009,” *The New York Times*, 1 March 2008, <http://www.nytimes.com/2008/01/31/world/africa/31iht-31iran.9634232.html>.

*provide their energy needs, as well as to use nuclear technology in scientific, technical, and manufacturing fields.*⁵²

Outside observers have for years considered Iran's nuclear program to be a major source of national pride, and at least a way for Ahmadinejad to generate more support for his administration.⁵³ International efforts to limit Iran's uranium enrichment ambitions have—according to some observers—served to reinforce the position of hard liners in Iran, further embedding a sense of pride in the Iranian nuclear program in the public consciousness, notwithstanding the diversity of opinion within Iran's young population.⁵⁴ A desire for nuclear power may be motivated predominantly by its symbolic value as a measure of progress and technological advancement, as the Iranian case suggests.

This driver is a particularly dangerous one in respect of proliferation concerns since nuclear weapons programs have historically generated the same kind of emotional appeal. There has been no shortage of boastful statements from North Korea following its October 2006 or May 2009 nuclear tests, for example. In June 2009, a North Korean spokesperson bluntly stated that, "As long as our country has become a proud nuclear power, the U.S. should take a correct look at whom it is dealing with."⁵⁵ Some states consider nuclear weapons to be the gold standard for a nation's military strength much in the same way some view nuclear energy as the gold standard for industrialization, so a peaceful nuclear program predicated on technological progress and prestige can be problematic. North Korea was pursuing otherwise peaceful nuclear technology through

⁵² Mahmoud Ahmadinejad, "Speech to Al-Qods International Conference in Jerusalem," (Tehran, 14 April 2006).

⁵³ Chuck Hagel, "At a Dangerous Crossroads: A Global Approach to Iranian Nuclear Ambitions," *The Harvard International Review* 30:1 (2008): 14-17.

⁵⁴ Hagel, 17.

⁵⁵ "NKorea Threatens to Harm US If Attacked," *ABC News*, 21 June 2009.

legitimate channels while concurrently pursuing secret nuclear weapons work as well, at least until June 1994 when it withdrew from the IAEA following suspicions about its illicit activities.⁵⁶ There are few assurances that the same national pride that can drive a peaceful nuclear program would not also have a similar effect on a nuclear weapons program. Drawing a straight line between the two would be an oversimplification, but several theoretical approaches to proliferation—such as Jacque Hymans’s psychological approach, which is explored further in chapter two—emphasize the connection between pride in technological progress and the desire for nuclear weapons.

Barriers to new nuclear energy

There are numerous barriers to a nuclear revival that will limit the number of new entrants in the coming decades. These barriers are likely to be especially detrimental to states aspiring to nuclear energy for the first time, in many cases preventing any real progress. They are also the reason that nuclear is only likely to play a small role in reducing carbon emissions in a timely manner, and in many cases why nuclear energy does not make economic sense for the countries pursuing it. They will also limit new latent nuclear weapons capabilities to 2030 since only a few states are likely to succeed in acquiring nuclear power⁵⁷, thereby making assessing proliferation risk an easier task.

⁵⁶ “North Korea Profile – Nuclear Chronology (1994),” Nuclear Threat Initiative, http://www.nuclearthreatinitiative.org/e_research/profiles/NK/Nuclear/46_623.html (accessed 3 September 2009).

⁵⁷ Further analysis in chapter four.

Cost and financing

Nuclear power plants have high up-front capital costs, so any new nuclear projects inevitably have financing challenges to face. Nuclear is furthermore considered by financial analysts to be a high risk investment due to frequent cost overruns, time delays, regulatory issues, cancelled projects and safety concerns.⁵⁸ Former Moody's Vice President Jim Hempstead stated, "The sheer size, cost and complexity of new nuclear construction projects can increase the business and operating risk of a utility, potentially exposing it to downward rating pressure over the intermediate- to longer-term horizon."⁵⁹ The result is that not only is nuclear expensive up-front, but it is also difficult to find willing financiers because of the risk involved.⁶⁰ The most telling example of the difficulties in financing new nuclear projects is in the United States where government loan guarantees are considered necessary for any new nuclear build, despite their initially being intended only for the first two or three new nuclear units.⁶¹ The difficulties in finding financiers are compounded in less wealthy nations, for example Lithuania's ongoing multi-year struggle to find a strategic investor willing to take a 50 to 60 percent stake in its new nuclear project.⁶²

The high risk also significantly increases the cost of capital for nuclear projects relative to other power plants, with an assumed cost of capital of at least 10 percent, already about 3 percent higher than for an equivalent coal plant.⁶³ A new 1,000 MW

⁵⁸ Richard W Cortright Jr., "Assessing the Credit Risks for New Nuclear Power Plants," Managing Director, US Utilities and Infrastructure Ratings, Standard and Poor's, The Reality of Renaissance, Nuclear Industry Conference and Trade Show 2009, Canadian Nuclear Association, 26 February 2009.

⁵⁹ "A utility's credit quality could be negatively impacted..." *Platts Nuclear News Flashes* (2007).

⁶⁰ Cortright Jr.

⁶¹ "The nuclear industry wants as much as \$100 billion in DOE loan guarantees..." *Platts Nuclear News Flashes* (2008)

⁶² "Interview – Lithuania needs help to salvage nuclear plan," *Reuters News*, 28 August 2009.

⁶³ International Energy Agency, "Energy Technology Perspectives 2008," 293.

nuclear power plant costs roughly between USD \$5 billion to \$6 billion, according to US figures calculated by Moody's.⁶⁴ The average construction time of nuclear power plants over the past 10 years is 64 months, which is considered an achievement given even slower construction in the 1980s and 1990s.⁶⁵ Depending on how long construction takes, the cost of financing new nuclear projects can add anything from 25 to 80 percent to the total cost of building the plant.⁶⁶ In July 2009, the Ontario government rejected a proposal for two new 1,200 MW CANDU reactors with a combined price tag of \$26 billion, three times higher than the province expected to pay, but supposedly an accurate reflection of the total cost—including financing—of the proposed new units.⁶⁷ The global financial crisis has exacerbated the financing issues with nuclear, according to MIT. The MIT study increased its overnight cost—which excludes the cost of financing—for nuclear energy from \$2,000/kW in 2003 to \$4,000/kW in 2009, a disproportionately higher increase than for coal or natural gas.⁶⁸ The increase was based on actual build costs in Japan and South Korea as well as projected costs for plants in the US.

The economics of new nuclear plants are not appealing and present a major challenge for the nuclear industry. Expansion is most likely to occur in states in which new nuclear build has strong government support, be it in the form of fully funding new nuclear projects or other measures such as loan guarantees to reduce the risk involved. For aspiring nuclear states, this means that only states that can afford the high initial capital

⁶⁴ Squassoni, 30.

⁶⁵ Nuclear Energy Agency, 51.

⁶⁶ Squassoni, 30.

⁶⁷ Tyler Hamilton, "\$26B cost killed nuclear bid," *The Toronto Star*, 14 July 2009, <http://www.thestar.com/business/article/665644> (accessed 4 September 2009).

⁶⁸ Deutch et al., *Update of the 2003 MIT Future of Nuclear Power*, 6. Coal increased from \$1,300/kW in 2003 to \$2,300/kW in 2009, and natural gas from \$500/kW in 2003 to \$850/kW in 2009.

outlay that nuclear entails are likely to move forward.⁶⁹ Of the 29 states pursuing nuclear, many seem unlikely to proceed at all because nuclear power is simply too expensive, particularly given that plans for new nuclear build in wealthy nations with advanced nuclear industries are floundering due to unreasonably high costs. A developing nation like Bangladesh, for example, which initially proposed its Rooppur reactor in 1961 to meet severe energy shortages, is probably not going to be built in large part because the country simply cannot afford it—its USD \$1 billion to \$2 billion price range for a 1,000 MW reactor is far too low.⁷⁰ The World Bank also excludes nuclear from its list of infrastructure projects it is willing to finance because costs are too often underestimated, are too high up front and nuclear projects are too large and inflexible, particularly for developing countries.⁷¹ Being able to afford and finance new nuclear projects is a major challenge in wealthy states with advanced nuclear industries—as the US and Canadian examples suggest—but the challenge is amplified many times in developing nations that simply lack the financial resources to afford multi-billion dollar infrastructure projects.

Physical infrastructure

Another major barrier to aspiring nuclear states is having the physical infrastructure to support a nuclear power plant. Physical infrastructure includes an adequate electrical grid, roads, a transportation system, and a safe and secure site.⁷² The harsh reality is that most developing countries—which includes many of the 29 countries currently pursuing nuclear for the first time—would need to invest millions (if not billions) of dollars on

⁶⁹ Or, perhaps, if a wealthy supplier state is willing to assist with financing on development grounds.

⁷⁰ Nuclear Energy Futures Project.

⁷¹ World Bank Environment Department, World Bank Technical Paper #154: Environmental Assessment Sourcebook Volume III,” April 1994: 83-89.

⁷² International Atomic Energy Agency, *Milestones in the Development of a National Infrastructure for Nuclear Power*, (Vienna: International Atomic Energy Agency, 2007), 39.

infrastructure upgrades for several years before hosting a nuclear plant would be a feasible option. Even smaller infrastructure projects for roads, railways, ports and power generation in a state like Nigeria, for example, suffer from chronic neglect often resulting from endemic corruption⁷³, and a nuclear power plant is a substantially larger project than these examples. Perhaps the greatest physical infrastructure barrier to aspiring nuclear states is an inadequate electrical grid. An inadequate electrical grid is a sure sign that any plans for nuclear energy would need to overcome a likely insurmountable barrier by 2030 before proceeding. The IAEA states that, “fundamental to the decision to employ nuclear power as a part of a national energy strategy is the size and configuration of the national electrical grid.”⁷⁴ According to the IAEA, as a general rule, no one generating unit should exceed 5 to 10 percent of the total installed capacity.⁷⁵ This means that for a new, 1,000 MW nuclear power plant, a country’s national electrical grid should have a reliable installed capacity of between 9,000 and 19,000 MW already. Many aspiring nuclear energy states do not meet this minimum requirement, as will be explored in chapter four.

Electrical grids are not necessarily limited to national borders, however, and buying and selling electricity is common in most of the world, but not necessarily among developing countries. To put the grid capacity question into perspective, the Baltic states—Estonia, Latvia and Lithuania—and Poland were planning to jointly build two 1,600 MW reactors to supply electricity to all four countries.⁷⁶ The old Soviet-design 1,300 MW Ignalina-2 nuclear plant in Lithuania currently exports electricity to Belarus, Latvia and Russia but is scheduled to be shut down due to EU regulations in 2009 and is

⁷³ Nathaniel Lewis, “*Nigeria and Nuclear Energy: Plans and Prospects*,” (Waterloo: Centre for International Governance Innovation, 2009 (forthcoming), 5.

⁷⁴ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*, 39.

⁷⁵ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*, 39.

⁷⁶ “Nuclear power share-out not delaying grid deal: Lithuania, Poland,” *Nuclear Energy Daily*, 10 October 2007, available at <http://www.energy-daily.com>.

in need of a replacement.⁷⁷ The three Baltic states combined had an electrical grid capacity of 8,268 MW in 2007 (Poland's was 30,954 MW), so new nuclear was only considered viable as a joint project. The project has been grounded because of the impact of the economic downturn on the finances of Estonia, Latvia and Poland, as well as political disagreements between Lithuania (the host country) and Poland.⁷⁸ Lithuania is trying to move forward with the project on its own but its chances of success are difficult to ascertain. The Baltic states nonetheless pursued this cooperative venture because national nuclear projects did not make sense for a host of reasons, one of which was their low individual electricity production levels.

Cooperative nuclear projects may in fact be the only option for many of the states interested in nuclear if their national energy infrastructure is not sizable enough to support a new nuclear plant. The Gulf Cooperation Council (GCC)—Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates—is the only group currently pursuing a joint nuclear plant, but there are doubts about the seriousness of its proposal.⁷⁹ Cooperative projects are arguably less of a proliferation risk since fewer facilities are built and fewer scientists required than under several national programs, thereby reducing the exposure to nuclear technology and expertise that the cooperating nations would otherwise have. In a cooperative arrangement the states involved are also accountable to one another, erecting another disincentive for any proliferation activities. The electrical grid barrier therefore has two positive implications from a strictly nonproliferation perspective. First, it limits the number of states that are able to move forward with nuclear

⁷⁷ Nuclear Energy Institute, *Source Book for Soviet-Designed Nuclear Power Plants* (Washington: Nuclear Energy Institute, 1997): 235.

⁷⁸ Platts, "No Ignalina-2 replacement near; Lithuania may revisit shutdown," *Nucleonics Week*, (New York: McGraw-Hill Companies, 2007), 5.

⁷⁹ Nuclear Energy Futures Project.

projects; and second, it encourages regional cooperation on nuclear projects, further reducing the number of national programs. Of course nonproliferation is not, however, a valid reason to hold these states back in their development.

Physical infrastructure challenges are not limited exclusively to the electrical grid. There are a large number of other requirements before the IAEA will provide support to a new nuclear project, including adequate roads, supporting power generators, a large water supply and waste facilities.⁸⁰ All of these have the potential to set back plans to develop nuclear power, especially in developing countries that often have poor roads. The IAEA has published a document titled “Milestones in the Development of a National Infrastructure for Nuclear Power” that includes a comprehensive list of hundreds of infrastructure targets—including physical infrastructure—for aspiring nuclear states to meet before they should commission a nuclear plant. Meeting all of the targets by 2030 is likely be a major challenge for developing states.

Regulatory infrastructure and safety culture

Current standards for nuclear safety among nuclear energy states—according to IAEA officials—are high considering the absence of legally binding obligations.⁸¹ Relative to other sources of energy, nuclear accidents can have widespread detrimental effects on human health and the environment. Whereas accidents in other types of power plants are generally contained, the fallout from a serious nuclear accident can cause death and suffering beyond state boundaries, as well as have significant environmental and

⁸⁰ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*.

⁸¹ Private conversation with International Atomic Energy Agency (IAEA) official, Vienna International Centre, (Vienna: October 2008).

economic consequences.⁸² The 1986 Chernobyl disaster is the obvious example with the United Nations estimating that 4,000 people will die of causes that can be directly linked to the accident, in addition to its many other costs to human health, the environment and economies.⁸³ According to IAEA officials, nuclear safety has come a long way and accidents on the scale of Chernobyl are less likely now, especially since operators improved or shut down these reactors.⁸⁴ Safety standards are high in large part because of recognition in the nuclear industry that a nuclear accident anywhere in the world is potentially a crippling blow to the industry writ large.⁸⁵

There is, as a result, a large burden on aspiring nuclear states to establish a good regulatory infrastructure and safety culture well in advance of construction of the first nuclear power plant. The responsibility to establish a satisfactory nuclear safety framework is embodied in the milestones established by the IAEA to guide aspiring nuclear states.⁸⁶ The IAEA states that it can take over 10 years for a state with no nuclear experience to prepare itself for a new nuclear plant.⁸⁷ Many aspiring nuclear states have furthermore shown that they struggle with managing any large investment or infrastructure projects for reasons ranging from political corruption to terrorism. Nigeria is again a useful example in this regard, as it has a long history of mismanaging large,

⁸² Brice Smith, *Insurmountable Risks* (Muskegon and Takoma Park: RDR Books and IEER Press, 2006: 184-201).

⁸³ World Health Organization, International Atomic Energy Agency and the United Nations Development Programme, "Chernobyl: the true scale of the accident," Joint News Release, 5 September 2005, <http://www.who.int/mediacentre/news/releases/2005/pr38/en/index.html> (accessed 4 September 2009).

⁸⁴ Private conversation with International Atomic Energy Agency (IAEA) officials, Vienna International Centre, (Vienna: October 2008).

⁸⁵ Private conversation with International Atomic Energy Agency (IAEA) official, Vienna International Centre, (Vienna: October 2008).

⁸⁶ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*, 16-20.

⁸⁷ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*.

complex projects.⁸⁸ Establishing the regulatory infrastructure and safety culture for a nuclear power plant over a 10-year period poses a major challenge for states like Nigeria that have struggled with smaller projects. Certain states, on the other hand, have dedicated large sums of money to prepare for a nuclear energy program. The United Arab Emirates is particularly active in paying nuclear scientists and engineers to assist it in developing its regulatory infrastructure and safety culture.⁸⁹ A country's ability to establish a satisfactory regulatory infrastructure and safety culture is dependent on its capacity to successfully manage large and complex projects and its ability to attract or train qualified personnel.

Personnel

The nuclear industry's stagnation since the early 1980s has dampened interest in nuclear science and engineering for a generation. Enrolment in nuclear science and engineering degrees worldwide dramatically decreased during that time, leading to what is now often referred to in the industry as the "missing generation".⁹⁰ To exacerbate the issue, a large portion of the nuclear labour force is set to retire within the next five years, including numbers as high as 40 percent of the workforce in France and the US.⁹¹ The reduced workforce means that any growth in the short-term will be limited by the number of qualified personnel.

There are two main consequences of personnel shortages for the nuclear revival and nonproliferation. The first is that it will be difficult for states to attract qualified personnel

⁸⁸ Nathaniel Lewis, *"Nigeria and Nuclear Energy: Plans and Prospects,"* (Waterloo: Centre for International Governance Innovation, 2009 (forthcoming)), 18.

⁸⁹ Private conversation with US Department of State official, US Department of State, (Washington, DC: April 2009).

⁹⁰ Murray Elston, "The Reality of Renaissance," Nuclear Industry Conference and Trade Show 2009, Canadian Nuclear Association, 26 February 2009.

⁹¹ Squassoni, 46-47.

to oversee their nuclear operations. The NEA notes that, “It is likely to take several years to redevelop the capability to construct new nuclear power plants, while maintaining the necessary high standards and the ability to keep projects on time and to cost.”⁹² The states that can do so are generally those that can afford to pay high salaries. The UAE, as already noted, has already made a name for itself by siphoning highly trained personnel from other companies and organizations to oversee its nuclear development by paying them large salaries, and as a result it remains poised as one of the more likely aspiring nuclear states to succeed in its plans.⁹³ The second implication is that the IAEA is facing a serious problem in attracting personnel for its safeguards inspectorate because it cannot afford to pay nearly as much as wealthy states or corporations. In June 2009, IAEA Director General Mohamed ElBaradei stated to the IAEA Board of Governors, “I will be cheating world public opinion to be creating the impression that we are doing what we’re supposed to do, when we know we don’t have the money to do it.”⁹⁴ As the primary organization tasked with preventing the diversion of peaceful nuclear technology to military uses not being able to attract the necessary personnel is a major challenge for the global nonproliferation regime.

Personnel issues therefore serve to both limit the scope of the purported nuclear revival, but also to limit the capacity of the IAEA to verify that new nuclear states are only pursuing peaceful nuclear technology. University enrolment in nuclear science programs has increased over the past several years in part because of recognition that

⁹² Nuclear Energy Agency, 316.

⁹³ Private conversation with US Department of State official, US Department of State, (Washington, DC: April 2009).

⁹⁴ Global Security Newswire, “IAEA Chief Slams Nations Over Funding,” *Global Security Newswire*, 17 June 2009.

there will be a labour shortage.⁹⁵ Training new personnel is time consuming, however, and will only delay new nuclear energy plans further. The delays in training new personnel are problematic for nuclear being a part of the solution to climate change since it is imperative for steps to be taken now for it to make a useful contribution.⁹⁶ The extent of personnel shortages will ultimately be dependent on the size and scope of the nuclear revival as determined by its other drivers and constraints and by the agility of both governments and the private sector in responding. Skills deficits will in the least delay some states' nuclear energy plans, potentially beyond 2030, but governments have the capacity to overcome them if they prioritize it. The question of whether states with advanced nuclear industries would be willing to train enough new personnel to satisfy global demand and not just their own does, however, remain.

Waste

The final major barrier to new nuclear energy states is that nuclear power generates highly radioactive waste that then needs to be stored for millennia. Concerns about nuclear waste are already widespread among countries that already have nuclear power, so it is likely to be an issue in other parts of the world as well. In the US, for example, controversy over what to do with all of its non-military nuclear waste is still not resolved despite the 1982 Nuclear Waste Policy Act (amended in 1987) that mandated a geological repository at Yucca Mountain, Nevada.⁹⁷ President Obama fulfilled a campaign promise to terminate the project by reducing its funding after it proved—over several decades of

⁹⁵ Murray Elston, "The Reality of Renaissance," Nuclear Industry Conference and Trade Show 2009, Canadian Nuclear Association, 26 February 2009.

⁹⁶ Deutch et al., *Update of the 2003 MIT Future of Nuclear Power*, 4.

⁹⁷ Nuclear Waste Policy Act of 1982, *US Senate Committee on Environment and Public Works*, 1982, <http://epw.senate.gov/public/?CFID=14052316&CFTOKEN=44353369> (accessed 4 September 2009).

campaigning by Nevada Senator Harry Reid—to be too politically volatile.⁹⁸ Few aspiring nuclear states are far enough along in their plans for the waste issue to materialize, so it remains to be seen whether or not it will be a major factor. So far there is little evidence that it is considered a barrier by aspiring nuclear states.

On balance

Weighing the drivers and barriers of new nuclear energy states, the prospects for several new nuclear energy programs emerging by 2030 are slim. The major barriers, particularly cost and physical infrastructure, are typically enough to prevent many of the 29 states considering nuclear from succeeding. The International Energy Agency's *World Energy Outlook 2008* summarized aspiring nuclear states' progress as follows:

*Over the past few years, a large number of countries have expressed renewed interest in building nuclear power plants, driven by concerns over energy security, surging fossil-fuel prices and rising CO2 emissions. Few governments, however, have taken concrete steps to build new reactors, beyond those that have had active nuclear power construction programmes in place for a long time.*⁹⁹

Aspiring states have so far only taken the easy steps towards nuclear power, without any major investment or sunk costs to date.¹⁰⁰ Given that many of them began their pursuit of nuclear power anywhere from 5 to 10 years ago the chances that their plans will proceed seem small.

Their small chance of success also means that the proliferation risk of the purported nuclear revival is going to be limited by the fact the risk simply will not materialize in the

⁹⁸ "Obama dumps Yucca Mountain," *World Nuclear News*, 27 February 2009.

⁹⁹ International Energy Agency, *World Energy Outlook 2008*, (Paris: Organisation for Economic Co-Operation and Development, 2008), 147.

¹⁰⁰ See: Nuclear Energy Futures Project.

form of new latent capabilities. The rapid dispersal of nuclear technology to dozens of new states that was originally envisioned by some will not happen. The prospect that a few of these states will succeed cannot, however, be ruled out. Measuring the nuclear weapons proliferation risk of a nuclear revival is therefore a function of both the chances that states' nuclear energy plans will succeed and their intentions if they do succeed.

Chapter 2 – Theories of nuclear weapons proliferation

Predicting the proliferation of nuclear weapons to new states is difficult. Despite over 60 years of nuclear proliferation, theories about why these weapons spread are not well developed and typically messy. There is no dominant theory of proliferation, or even one that is widely acknowledged as being able to make predictions better than the rest. Some theories have diminished in stature. The theory of technological determinism, for example, is not usually accepted since predictions that it was merely a matter of time before nuclear weapons were assembled abundantly around the globe have proven false. The proliferation debate is still largely dominated by a select few schools of thought that have existed for decades. Even within these schools of thought there are different approaches, as exemplified by some of the realist approaches to proliferation that will be discussed shortly. The challenge is that there are many possible variables that should be considered to understand why a state chooses to take the nuclear option.

A predominantly realist approach to proliferation published in the *Journal of Conflict Resolution* by Dong-Joon Jo and Erik Gartzke in 2007, for example, highlights eleven criteria regarding the willingness of and opportunity for states to pursue nuclear weapons.¹⁰¹ Their research concludes that—since major powers already have nuclear weapons—it is regional and other middle powers that are most likely to seek them next; however, they qualify that conclusion by stating that, “Many of these states have already attained latent nuclear weapons production capabilities but have refrained from nuclear

¹⁰¹ Dong-Joon Jo and Erik Gartzke, “Determinants of Nuclear Weapons Proliferation,” *Journal of Conflict Resolution* 41 (2007): 186.

weapons development for a variety of idiosyncratic reasons.”¹⁰² Their need to cite “idiosyncratic reasons” for why their predictions are not always true is indicative of the difficulty in devising a comprehensive theory of proliferation. Selecting the right variables and synthesizing them into a predictive theory has been the bane of proliferation theorists throughout the atomic era, and as such, we still have a limited capacity to predict what will lead states to pursue a nuclear capability. Theories that base predictions on too few variables are often too restrictive to be of any real value, and history has on many occasions proven them false. Theories that acknowledge and employ a large number of variables, on the other hand, may do well to explain past proliferation decisions, but lack predictive validity because of the sheer number of factors involved. This chapter will discuss these challenges in the context of the major theoretical approaches to proliferation.

That predicting proliferation is difficult does not, however, mean that existing theories do not have a lot to offer. This chapter will attempt to demonstrate that each theory in its own way provides us with a better understanding of the dynamics of proliferation, and consequently allows us to identify states or regions that appear particularly prone to proliferation. The five major theoretical approaches to explaining nuclear proliferation are:

1. Technological determinism
2. Realism
3. Liberalism
4. Domestic determinants
5. Sociological and psychological

¹⁰² Jo and Gartzke, 187.

These categories are not necessarily mutually exclusive, and some of the more complex theories of proliferation take more than one approach into consideration. The major theories of proliferation nevertheless emphasize a single variable or multiple variables associated with one of these approaches as the primary driver(s) of proliferation.

Technological determinism

Early predictions of proliferation were based on a fear that once the technology was available, states would pursue nuclear weapons irrespective of other considerations. These predictions were the underlying assumption of some of the Manhattan Project scientists, appalled by what they had accomplished, in their early efforts to promote the international control of nuclear energy. A representative of the Federation of American Scientists (FAS)—founded by Manhattan Project scientists in 1945—testified before Congress that, “There can be no real national security in a world in which many nations possess atomic weapons.”¹⁰³ Director of the Manhattan Project Robert Oppenheimer went as far as advocating destruction of the then small US atomic weapons stockpile as the only way to avoid nuclear war in the future.¹⁰⁴ The underlying rationale behind assumptions about the rapid spread of nuclear weapons was that technological progress was an inevitable part of the human condition, and that as societies advanced they would seek out useful attainable technologies. In 1953, US President Dwight Eisenhower in his now famous ‘Atoms for Peace’ speech to the UN General Assembly stated, in reference to nuclear weapons, that, “The knowledge now possessed by several nations will

¹⁰³ “The Atomic Scientists Back the McMahon Bill,” *Bulletin of the Atomic Scientists of Chicago* 1:4 (1946): 1.

¹⁰⁴ “Senate Hearings on Atomic Energy,” *Bulletin of the Atomic Scientists of Chicago* 1:2 (1945): 3.

eventually be shared by others, perhaps all others.”¹⁰⁵ Pursuit of nuclear weapons and success in acquiring them were considered one and the same. While some states would undoubtedly be quicker to progress than others, all would eventually have the technical capacity to design and build their own nuclear weapons. This theory posited that nuclear technology itself drives nuclear proliferation.¹⁰⁶

Over six decades later there are only nine nuclear armed states in contrast to the dozens of technologically able states that have foregone nuclear weapons, so technological determinism as a theory of nuclear proliferation is effectively obsolete. As a result there is little literature on the subject relevant to the contemporary debate about nuclear proliferation. Stephen Meyer’s 1984 contribution, *The Dynamics of Nuclear Proliferation*, effectively put the theory technological determinism to rest by applying a decision-making model to observations about proliferation decisions. Meyer concluded that, “one cannot distinguish between countries that go nuclear and those that do not merely by examining relative capabilities.”¹⁰⁷ He shows that by 1981, there were approximately 38 states with the technology to develop nuclear weapons, but only 12 of them had actively pursued them at one point.¹⁰⁸ Canada, despite its participation in the Manhattan Project, was the first technologically able country to officially forego building its own nuclear weapons, followed by most European states.¹⁰⁹ By 1984 even previous advocates of technological determinism were acknowledging the theory was wrong, such

¹⁰⁵ “Address by Mr. Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly,” 8 December 1953, http://www.iaea.org/About/history_speech.html (accessed 13 September 2009).

¹⁰⁶ Tanya Ogilvie-White, “Is There a Theory of Nuclear Proliferation? An Analysis of the Contemporary Debate,” *The Nonproliferation Review*, Fall 1996: 44.

¹⁰⁷ Stephen M. Meyer, *The Dynamics of Nuclear Proliferation* (Chicago: The University of Chicago Press, 1984), 165.

¹⁰⁸ Meyer, 78-79.

¹⁰⁹ See: Brian Buckley, *Canada’s Early Nuclear Policy: Fate, Chance and Character*, (Montreal: McGill-Queen’s University Press, 2000).

as Charles Kegley refuting his own ‘capabilities model’ in a 1980 article.¹¹⁰ Kegley’s theory argued that states pursued nuclear weapons once they had the technological and economic ability to do so.¹¹¹ Decisions about whether or not to acquire nuclear weapons were evidently more complicated than initially predicted.

Initially, thinking about proliferation as inevitable may have contributed to world leaders promoting ways of preventing it, so the theory was not without merit. Meyer’s research in fact indicates that until 1956 there may have been a technological imperative operating with only one capable state, Canada, opting not to pursue nuclear weapons¹¹², so it may well be that recognition of a potential technological imperative helped to prevent it from becoming true. Eisenhower’s ‘Atoms for Peace’ speech to the UN and the subsequent creation of the IAEA to regulate the spread of nuclear materials were both positive products of the fear that technological determinism was accurate. John F. Kennedy’s famous prediction in 1963 that the United States could face 15 to 25 new nuclear armed states by the 1970s was wrong, but did contribute to raising awareness about the (perceived) threat of proliferation.¹¹³ Technological determinism has run its course as a theory of proliferation, but that may be in part because of the actions taken by states since 1945 to ensure that the pessimistic future it predicted did not come to pass. Therein lays perhaps the greatest challenge to devising a lasting theory of proliferation—as long as states are actively engaged in trying to prevent proliferation by targeting its drivers, new variables that undermine those drivers are constantly being introduced.

¹¹⁰ Charles Kegley, “International and Domestic Correlates of Nuclear Proliferation: A Comparative Analysis,” *Korea and World Affairs* 4 (1980).

¹¹¹ Kegley.

¹¹² Meyer, 78.

¹¹³ John F. Kennedy, “News Conference Number 52,” 21 March 1963, http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Press+Conferences/003POFO5P+ressconference52_03211963.htm (accessed 13 September 2009).

Technological determinism is nevertheless useful in that it elucidates the connection between technological progress and latent ability. While many states do have the technical ability to design and build nuclear weapons, they have chosen not to. That they have chosen not to, however, does not change the fact that their technological progress has provided them with the capacity to do so. The main distinction between a state that is hedging and a state that is not is therefore one of intention rather than capacity since capacity can exist in each case. Technology is a necessary condition for a decision to pursue nuclear weapons, but not a sufficient one.¹¹⁴ As Meyer aptly put it:

*As it pertains to nuclear proliferation there is no technological imperative, but this does not mean that technology does not affect proliferation decision making. A country's relative level of nuclear development can act as a conducement to proliferation decisions.*¹¹⁵

As a theory of proliferation, technological determinism is not useful for determining most likely proliferators in the nuclear revival, but it does support the conclusion expressed in chapter three that technical capability is one influence—albeit a minor influence according to the prevailing theories of proliferation—on motivation.

Realism

Perhaps the most lasting approach to proliferation has been the realist approach: that states make decisions to pursue or forego nuclear weapons based on their strategic interests. The realist approach dominated thinking about nuclear weapons proliferation during the Cold War, in large part because it does provide a convincing justification for why states pursue nuclear weapons. Underpinning realist theory is the notion that states

¹¹⁴ Meyer, 75-90.

¹¹⁵ Meyer, 90.

are rational actors in a competitive international system, and will therefore make decisions that will serve their self-interest or maximize their power. Hans Morgenthau first proposed the concept of political realism in international relations in 1948 in his highly influential *Politics Among Nations*, in which he argued that relative power was the driving force behind all international relations.¹¹⁶ The implication of this notion is that states will make nuclear decisions in order to increase their relative power in the international system. Morgenthau, for example, viewed disarmament negotiations between the US and Soviet Union as a struggle for power:

*On the level of the struggle for power, the conflict is posed in terms of competition for military advantage, each side trying, at worst, to maintain the existing distribution of power and, at best, to change it in its favor. Of this competition, the controversy about nuclear disarmament is merely an outward expression, following the contours of the conflict as the cast of clay follows the shape of the form into which it is molded. As the cast can only be changed by changing the mold, so the problem of nuclear disarmament can only be solved through a settlement of the power conflict from which it has arisen.*¹¹⁷

Nuclear weapons, to Morgenthau, are merely another proxy in the power struggle between nations.

Kenneth Waltz introduced neorealism in 1979¹¹⁸, which brought “polarity” into proliferation discussions in the 1980s. He raised interesting questions about how states behave differently in a bipolar versus a multipolar world.¹¹⁹ Neorealism is distinct from classical realism because it introduces the structure of the international system into the equation rather than focusing just on the competing interests of independent states in their

¹¹⁶ Hans J. Morgenthau, *Politics Among Nations: The Struggle for Power and Peace*, Third Edition (New York: Alfred A Knopf, 1962): 4-15.

¹¹⁷ Morgenthau, 401-402.

¹¹⁸ Kenneth N. Waltz, *Theory of International Politics*, (Massachusetts: Addison-Wesley Pub. Co., 1979).

¹¹⁹ For a compilation of the views of the foremost advocates and critics of neorealism see: Robert Keohane ed., *Neorealism and Its Critics* (New York: Columbia University Press, 1986).

various bilateral relationships.¹²⁰ Waltz has consistently argued throughout his career that the gradual spread of nuclear weapons is a boon, claiming that, “Although the possibility of war remains, nuclear weapons have drastically reduced the probability of it being fought by the states that have them.”¹²¹ Others have disagreed, most notably Scott Sagan in a debate between the two theorists published in 1995 titled *The Spread of Nuclear Weapons: A Debate*.¹²² Sagan is understandably less optimistic in trusting that all political leaders and military establishments will act rationally to external forces and thus, as Waltz’s logic dictates, never use their nuclear weapons.¹²³ Waltz’s basic argument is that nuclear weapons will spread—and indeed should, gradually—as other states recognize their benefits to national security and stability. Waltz has, however, acknowledged that he “believes that nuclear proliferation dynamics are far too complex for general theories of international relations to explain.”¹²⁴ Regardless, the wisdom that should be taken from Waltz’s view is that states will pursue nuclear weapons if it is in their strategic interests, which are determined in large part by the structure of the international system.

Past proliferation activities have been explained using realist theory, suggesting it does have merit as an explanatory theory of proliferation, if not a predictive one. As Scott Sagan puts it, it is not difficult to perceive the history of proliferation as a “strategic chain reaction”: the US program was initiated by fears of a German program during the Second World War; the Soviets viewed it as critical to maintain strategic parity with the US

¹²⁰ Buzan et al. expand on neorealism by further exploring the relationship between the structure of the international system and its individual units: Barry Buzan, Charles Jones and Richard Little, *The Logic of Anarchy* (New York: Columbia University Press, 1993).

¹²¹ Kenneth N. Waltz, “Nuclear Myths and Political Realities,” *The American Political Science Review* 84:3 (1990): 744.

¹²² Scott D. Sagan and Kenneth N. Waltz, *The Spread of Nuclear Weapons: A Debate* (New York/London: W.W. Norton & Company, 1995).

¹²³ Sagan and Waltz, 116-118.

¹²⁴ Kenneth N. Waltz, “A Reply,” *Security Studies* 4 (1995): 804.

following the Hiroshima and Nagasaki bombings; Britain and France were likewise in the shadow of the Soviet Union and in need of their own deterrent; once Sino-Soviet relations soured a Chinese bomb became an imperative for the Chinese, which later drove India and subsequently Pakistan to do so as well.¹²⁵ There is a strategic justification for nuclear weapons in all of the major nuclear weapon states, even if we do not automatically accept that that justification necessarily translates into causality.¹²⁶

Where realist theories of proliferation often fall short, however, is in that they often overlook domestic determinants of nuclear proliferation. They essentially “black box” the issue of nuclear proliferation by only accounting for security considerations, thereby discounting the numerous other factors that ultimately contribute to decision-making processes.¹²⁷ As one author puts it, “[Realist] theories overlook the point that states have multiple goals, both domestic and international, and that these goals are interlinked.”¹²⁸ It is too easy to fall into the trap of assuming that these states are unitary actors, and explaining their decisions as such. There is often a complex interplay of stakeholders with varying opinions that need to be considered. North Korea justified its May 2009 nuclear test and the series of missile tests that followed on the grounds of deterring US aggression¹²⁹—a seemingly clear realist explanation for aggressive action—but commentators still widely believe that the acts have more to do with internal politics and

¹²⁵ Scott D. Sagan, “Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb,” *International Security*, Vol. 21, No. 3 (1997): 58.

¹²⁶ South Africa and North Korea both justified their nuclear arsenals on national security grounds as well. South Africa in response to an unstable region, and as a way to keep both the Soviets and Americans at bay. North Korea frequently cites “American imperialism” as reason for its small nuclear arsenal.

¹²⁷ Ogilvie-White, 44.

¹²⁸ Ogilvie-White, 48.

¹²⁹ Including threats to “wipe out” the US if it continues its supposed “imperialism”: “North Korea threatens to ‘wipe out’ US,” *CBC News*, 24 June 2009, <http://www.cbc.ca/world/story/2009/06/24/north-korea-nuclear-standoff062409.html> (accessed 13 September 2009).

securing a place for Kim Jong Il's successor than a perceived threat from the US.¹³⁰ While the presence of a national security justification for nuclear weapons may be necessary, it does not always sufficiently explain why some states pursue them while others forego them.

Realist explanations for why states pursue nuclear weapons can be a challenge to address juxtaposed against the motivation for nuclear energy. There is a disconnect between a state's determination of supreme security interests and the time it takes for a state to pursue the bomb via a peaceful nuclear program. It depends on how a state defines its security interests. Obviously a peaceful nuclear energy program is not useful in combating short-term security threats, so aspiring nuclear energy states would in essence be predicting their security situations at least ten years into the future. By this logic some of the expected threats, such as Iran acquiring the bomb, may not materialize at all and the actual drivers of nuclear proliferation would be perception and fear rather than tangible security issues. States may be interested in acquiring an otherwise peaceful nuclear infrastructure to hedge against certain threats materializing. Sagan describes the practice of viewing proliferation through a security lens as being historically unsound:

*An all too common intellectual strategy in the [proliferation] 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. Similarly, scholars too often observe a state decision not to have nuclear weapons and then work backwards to find the change in the international environment that "must" have led the government to believe that threats to national security were radically decreasing.*¹³¹

¹³⁰ David E. Sanger, "North Korean Leader is Said to Pick a Son as Heir," *New York Times*, 2 June 2009, <http://www.nytimes.com/2009/06/03/world/asia/03korea.html> (accessed 13 September 2009).

¹³¹ Sagan, 63.

Regardless of what decisions aspiring nuclear energy states make regarding diversion of their peaceful program to nuclear weapons there will be a strategic explanation for it. If a Middle Eastern state acquires the bomb, realists can explain it as a strategic response to Israeli weapons or Iranian ambition. If that same state were to forego the bomb, however, the state could be seen as furthering its interests by remaining in good standing with the international community and securing allies. Nuclear hedging fits neatly here because it is one way for states to obtain capability in the long-term without committing itself to illicit nuclear weapons pursuit. Nuclear hedging is a product of strategic motivations for nuclear weapons derived from realist theory. Strategic considerations are important in assessing the motivations of the 29 aspiring nuclear energy states, but they are only one part of the puzzle.

Liberalism

Liberalism rejects the view that the international system is necessarily competitive, and instead posits that states can and do cooperate to their mutual benefit. Liberalism does not provide a theory of proliferation, but it does provide a counter-argument to realist interpretations by questioning the prominence of strategic determinants in assessing state motivations for nuclear weapons. Robert Keohane and Joseph Nye are two of the leading theorists who have challenged realist interpretations of power in the international system, most notably in their co-authored 1977 publication *Power and Interdependence: World Politics in Transition*. They argued that “conditions of contemporary international interdependence tend to limit the abilities of statesmen [*sic*] to manipulate asymmetrical

interdependence.”¹³² The interdependencies within the international system therefore mean that power relationships are more complex than just military strength, and that those relationships operate at asymmetrical levels, defined broadly as the “potential to affect outcomes.”¹³³ Perhaps the most important contribution of Keohane and Nye’s work is that their understanding of power and interdependence holds in cooperative interstate relations, so they are providing a theoretical understanding of power that can also explain international cooperation.

The nonproliferation regime is a good example of asymmetrical interdependencies within the international system. The 1968 Nuclear Non-Proliferation Treaty (NPT) is a remarkable success. With 189 of the 192 states in the UN system party to the treaty it has near-universal membership. It legally binds all non-nuclear weapon states not to acquire or attempt to acquire nuclear weapons in return for the right to peaceful nuclear technology subject to nuclear safeguards, while committing existing nuclear weapon states to disarmament.¹³⁴ The treaty is a cooperative endeavor with the ultimate objective of reducing the threat of nuclear weapons to all, although that is not to say that power is not important. For example, Egypt has for years pursued peaceful nuclear technology as a party to the treaty, while opposing strengthening its verification measures and using it to denounce Israel for having nuclear weapons.¹³⁵ The point is that while liberalism emphasizes that cooperation is possible within the international system, it does not, as Keohane and Nye indicate, reject the importance of power. Instead it offers a different interpretation of power that does not overlook states’ willingness to cooperate to meet

¹³² Robert O. Keohane and Joseph S. Nye, *Power and Interdependence: World Politics in Transition* (Scott, Foresman and Company, 1977), 18.

¹³³ Keohane and Nye, 11.

¹³⁴ “Treaty on the Non-Proliferation of Nuclear Weapons,” 1968, <http://www.iaea.org/Publications/Documents/Infocircs/Others/infocirc140.pdf> (accessed 19 September 2009). See articles I, IV and VI.

¹³⁵ Egypt is analyzed in more detail in chapter 5.

common goals, even if doing so means acting in ways that do not appear to be in a state's immediate self-interest. Egypt foreswearing nuclear weapons despite a violent, conflict-prone history with nuclear-armed Israel is just one such example.

Although liberalism has not yielded many theories explaining why some states proliferate and others do not, Glenn Chafetz proposed one notable alternative in a 1993 article in *Security Studies* titled "The End of the Cold War and the Future of Nuclear Nonproliferation: An Alternative to the Neo-realist Perspective."¹³⁶ His model divided states into "core", typically liberal democratic states, and "periphery" states, arguing that core states have developed shared values that have led to what he calls a "pluralistic security community."¹³⁷ States on the periphery on the other hand have not, according to Chafetz, developed liberal democratic values and are more likely to regard each other as military threats and thus develop nuclear weapons.¹³⁸ Chafetz's theory does not withstand much scrutiny, however, as it is in too many cases not supported by the evidence. According to the Economist Intelligence Unit's "Democracies Index 2008" among the states with nuclear weapons, Britain, France, India, Israel and the United States are either democracies or flawed democracies, Pakistan and Russia are hybrid regimes, while China and North Korea are authoritarian regimes.¹³⁹ His theory does not appear to help explain why the existing nuclear weapon states chose nuclear weapons, so its predictive validity

¹³⁶ Glenn Chafetz, "The End of the Cold War and the Future of Nuclear Nonproliferation: An Alternative to the Neo-realist Perspective," *Security Studies* 2 (1993).

¹³⁷ Chafetz, 128; Ogilvie-White, 49.

¹³⁸ Chafetz, 146; Ogilvie-White, 49.

¹³⁹ Economist Intelligence Unit, "Index of Democracy 2008," *The Economist*, 2008, <http://graphics.eiu.com/PDF/Democracy%20Index%202008.pdf> (accessed 19 September 2009).

is questionable. Empirical evidence has routinely demonstrated that liberal democratic values and nuclear proliferation are not closely correlated.¹⁴⁰

While it does not yield a predictive theory of proliferation, liberalism introduces variables, such as international legal obligations and interdependencies in the international system, that can be useful in assessing the motivations of aspiring nuclear states. The nonproliferation regime and the international community create major disincentives for a state to illegally pursue nuclear weapons. The safeguards system of the IAEA and the intelligence capabilities of states has created a climate in which avoiding detection of illicit activities is challenging. A potential proliferating state would need to be willing to accept the implications of noncompliance with the NPT, so factors relating to a country's dependence on other states—be it economic or otherwise—become important in assessing their willingness to attempt developing a nuclear weapon. In a world increasingly characterized by economic and social integration, the candidates for noncompliance seem to be shrinking rather than expanding.

Domestic determinants

During the 1980s and 1990s the focus of nuclear proliferation theory began to shift somewhat from broader strategic analysis to the domestic factors that influence state decisions to pursue or forego nuclear weapons. Mitchell Reiss's *Without the Bomb: The*

¹⁴⁰ See, for example: Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia & the Middle East* (Princeton: Princeton University Press, 2007): 37-40. Or, for a statistical analysis see: Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security* 34:1 (2009): 30-31.

Politics of Nuclear Proliferation, was one of the early studies that introduced domestic factors into proliferation theory. He concluded that:

*[The international nonproliferation] regime is more complex and more extensive than is generally understood. It does not consist solely, or even primarily, of the international nonproliferation arrangements with which it is most commonly associated. Domestic pressures, bilateral incentives, and the general consensus against nuclear weapons and nuclear proliferation are also integral parts of this regime.*¹⁴¹

Scott Sagan's criticisms of neo-realism—discussed above—were also partly based on the recognition that domestic factors cannot be neglected in understanding nuclear choices. As Sagan puts it, "I have no quarrel with the argument that the largest number of past and even current active proliferant cases are best explained by the security model. But the evidence...strongly suggests that multicausality...lies at the heart of the nuclear proliferation problem."¹⁴² Theories of proliferation that focus on domestic determinants recognize that there are numerous internal and external factors that play a major role in nuclear decision-making. They emphasize that states are made up of individuals and groups with differing agendas and influence. Sagan identifies three particularly influential groups of actors in nuclear decision-making; namely, the nuclear establishment (such as nuclear scientists), military leaders and political leaders.¹⁴³ George Perkovich's *India's Nuclear Bomb*, for example, explains that nuclear scientists were responsible for India acquiring nuclear weapons.¹⁴⁴ Domestic determinant theories of proliferation avoid the problem of treating states as unitary actors by examining their component parts.

¹⁴¹ Mitchell Reiss, *Without the Bomb: The Politics of Nuclear Nonproliferation* (New York: Columbia University Press, 1988): 265.

¹⁴² Sagan, 85.

¹⁴³ Sagan, 63-65.

¹⁴⁴ George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999).

Nuclear decision-making is an important component of theories that highlight the domestic determinants of proliferation. Stephen Meyer suggests that the decision to pursue a nuclear weapons program is not a single irreversible decision, but a three step process in which a state could falter at any step and reverse its decision.¹⁴⁵ According to Meyer, the first step involved the decision to develop a latent capability to develop nuclear weapons, typically the necessary infrastructure and expertise.¹⁴⁶ Meyer is one of the few proliferation experts to incorporate the nexus between peaceful nuclear technology and nuclear weapons into a theoretical understanding of why states proliferate. The challenge with identifying this step—and the one this thesis attempts to address—is distinguishing between a state genuinely interested in the peaceful benefits of nuclear technology and one seeking a latent nuclear weapons capability. Meyer's second step is the decision to proliferate, or to actively begin a nuclear weapons research and development program.¹⁴⁷ At this stage intention is clear, but technical barriers or external pressure can and have effectively ended nuclear ambitions, so it is by no means a surety yet. At the third stage, a state decides to implement an operational nuclear weapons program, upon completion of it has then "acquired the bomb".¹⁴⁸ At each stage in this process numerous technological, political, economic or societal factors can slow down or halt the process. Meyer's essential point is that the decision to pursue nuclear weapons is not an isolated decision, but rather an extended process that must overcome various internal and external pressures throughout.

¹⁴⁵ Meyer was previously introduced for his debunking of technological determinism as a valid theory of proliferation.

¹⁴⁶ Meyer, 5-6.

¹⁴⁷ Meyer, 6.

¹⁴⁸ Meyer, 6.

Etel Solingen's 2007 study of nuclear proliferation, *Nuclear Logics: Contrasting Paths in East Asia & the Middle East*, is a valiant effort to incorporate a host of strategic, economic and political variables into an understanding of what drives decisions to pursue nuclear weapons.¹⁴⁹ Solingen presents the dynamic between the political survival of a leader (or party) and the state's international integration with the rest of the world as one way to view why some states pursue nuclear weapons and others do not.¹⁵⁰ Although Solingen makes recommendations about how her findings can advance research in each of the main theoretical approaches to proliferation, her methodology reflects her acceptance of the multicausality of proliferation decisions, of which domestic determinants are one factor. Solingen indeed states that, "identifying domestic models that underlie nuclear shifts...takes us several steps beyond structural power explanations in understanding how external and internal factors interact to produce changes in nuclear behaviour."¹⁵¹ The logic of her argument is that international integration is important to the political survival of various leaders depending on the needs and expectations of domestic groups. Countries that have many interdependencies with the rest of the world are less likely to pursue nuclear, and vice versa.¹⁵² The inward or outward looking nature of a state, as well as the needs and expectations of society become factors that, according to Solingen, need to be considered in determining the nuclear intentions of states.

Much of the nuclear nonproliferation regime has focused on technology denial and detecting noncompliance as ways of limiting proliferation: the so-called supply side of

¹⁴⁹ Solingen.

¹⁵⁰ Solingen, 287.

¹⁵¹ Solingen, 285.

¹⁵² Solingen provides extensive evidence supporting this hypothesis in each of her nine case studies contrasting nuclear decision-making in East Asia (Japan, South Korea, Taiwan and North Korea) and the Middle East (Iraq, Iran, Israel, Libya and Egypt).

proliferation. Supply side measures, such as technology denial and safeguards, are easier than addressing the root causes of a desire for nuclear weapons, but not more important. Nobel Laureate and widely-respected nonproliferation expert Thomas Schelling has, however, for over three decades and to this day argued that nonproliferation efforts need to emphasize understanding and working to remove the incentives that drive demand for nuclear weapons in the first place.¹⁵³ Similar statements have been echoed by Hans Blix and Mohamed ElBaradei, two previous director-generals of the International Atomic Energy Agency. At the Carnegie Endowment's annual conference in 2004 Blix simply stated: "No incentives, no weapons, no use."¹⁵⁴ In an interview also in 2004, ElBaradei said, "technology has come out of the box...we need to have a different approach to handling issues of non-proliferation. This should not consist only of controlling the source of the water, but we must look at the reasons why countries are trying to acquire nuclear weapons."¹⁵⁵ Analysing domestic decision-making processes regarding nuclear weapons is one possible way to further inform the debate about what drives a select few states to pursue nuclear weapons while most others to refrain.

In an increasingly globalized and interdependent world the prospects for nuclear proliferation do not appear as dire as they otherwise might. The political and economic cost of isolationism is perhaps greater now than it was in the past. In Iran, public opposition to President Ahmadinejad and the Iranian nuclear program are not uncommon, and although unsuccessful in achieving their goals, the June 2009 protests over the defeat

¹⁵³ Closed-door meeting with Thomas Schelling and others, Nuclear Threat Initiative, (Washington, DC: April 2009).

¹⁵⁴ Carnegie Endowment Conference, 21 June 2009 (Washington, DC), originally quoted in Solingen, 249.

¹⁵⁵ "Al-Arabiya Interviews IAEA Chief on Libya's Cooperation, Iran, Proliferation," *Al-Arabiya TV*, 24 February 2004, originally quoted in Solingen, 249.

of reformist Mir Hosein Mousavi are a sure sign that many Iranians, particularly younger Iranians, are unhappy with the status quo.¹⁵⁶ The decision-making process for pursuing a nuclear weapon program seems to be an increasingly difficult one for states to traverse as global integration proceeds.

Sociological and psychological

A more recent challenge to the conventional wisdom of what motivates some states to pursue nuclear weapons are sociological and psychological approaches that emphasize identity as the lens through which to better understand state decisions. These approaches are derived from constructivist theories of international relations and explain nuclear decisions as a function of the belief systems of various groups and individuals. Views of the utility and worth of nuclear weapons is a matter of perception that varies across and within cultures. How those views are constructed is dependent on the environment in which an individual or group is exposed to. As Sagan describes the perspective, “state behaviour is determined not by leaders’ cold calculations about the national security interests or their parochial bureaucratic interests, but rather by deeper norms and shared beliefs about what actions are legitimate and appropriate in international relations.”¹⁵⁷ Sociological and psychological factors are therefore important in assessing state motivations for nuclear weapons.

Studying the belief systems of individuals and how they conceive of the world is challenging enough, but to turn those studies into an explanatory theory of proliferation is

¹⁵⁶ “Is the dream already over?” *The Economist*, vol. 391, no. 8637: 53-55.

¹⁵⁷ Sagan, 73.

a momentous task.¹⁵⁸ The problem becomes one of needing to account for far too many variables at various levels of society to be able to make predictions about proliferation. One way of resolving this problem has been to take the so-called “epistemic communities” approach, which more specifically targets the nuclear elite in a proliferation context and how their beliefs about nuclear weapons are formed.¹⁵⁹ Emanuel Adler wrote an article in 1992 in *International Organization*, titled “The Emergence of Cooperation: National Epistemic Communities and the International Evolution of the Idea of Nuclear Arms Control,” that addressed the contribution of epistemic communities to arms control.¹⁶⁰ Adler argued, citing several examples from US-Soviet relations during the Cold War, that, “the role played by the arms control epistemic community in the emergence of nuclear arms control between the superpowers was significant and multifaceted.”¹⁶¹ While he does emphasize arms control, Adler also highlights the key role of former Manhattan Project scientists in creating the international nonproliferation regime and the importance of it to limiting the proliferation of nuclear weapons.¹⁶² The problem as it pertains to predicting which states will pursue the bomb then becomes one of determining how various epistemic communities influence the ultimate decision to pursue nuclear weapons, which can vary depending on a number of organizational and domestic factors. Thinking about societal belief systems is one important way to look at proliferation, but these theories—like most proliferation theories—tend to falter at the level of operationalization.

¹⁵⁸ For an excellent analysis of why identity is more complicated than many international relations scholars give it credit for see: Amartya Sen, *Identity and Violence: The Illusion of Destiny* (New York: W. W. Norton & Company, Inc., 2006).

¹⁵⁹ Ogilvie-White, 52.

¹⁶⁰ Emanuel Adler, “The Emergence of Cooperation: National Epistemic Communities and the International Evolution of the Idea of Nuclear Arms Control,” *International Organization* 46:1 (1992).

¹⁶¹ Adler, 140.

¹⁶² Adler, 101-105.

Perhaps the most revealing example of a why cultural identity matters in nuclear weapons decisions is anti-nuclear sentiments in Japanese society.¹⁶³ As the only country to have suffered from a nuclear attack those sentiments seem perfectly logical, and undoubtedly influenced decisions about foregoing nuclear weapons. But to cite only Hiroshima and Nagasaki as the reference points for nuclear sentiment in Japan is an oversimplification. As Japan underwent a series of societal and cultural changes after the Second World War, the conceptualization of nuclear weapons in Japan likely changed alongside its demilitarization and the emergence of Japan as the world's second largest economy.¹⁶⁴ The psychological approach to proliferation argues that the determinants of proliferation—whether strategic, legalistic or domestic—cannot be universalized across all states because the importance and acceptance of each determinant is dependent on a unique cultural context in each case.

Jacques Hymans's 2006 study, titled *The Psychology of Nuclear Proliferation: Identity, Emotions and Foreign Policy*, is one of the first to empirically assess how the identity of state leaders can lead to pursuit or rejection of nuclear weapons.¹⁶⁵ He examines the identity of the nation's leader as a reflection of societal beliefs and values, rather than the substantially more challenging task of considering identities within a society. His approach perhaps overemphasizes the role of state leaders in nuclear decisions—not to say that they are not important—in lieu of considering broader cultural beliefs about nuclear weapons. In doing so he does, however, avoid the trap of generalizing about a broader 'national identity' within societies that are always more

¹⁶³ Some authors even refer to Japanese anti-nuclear sentiments as Japan's "nuclear allergy": George H. Quester, "Japan and the Nuclear Non-Proliferation Treaty," *Asian Survey* 10:9 (1970).

¹⁶⁴ A. Ivanov and Y. Dmitriev, "Anti-War Movement in Japan," *Far Eastern Affairs* 1 (1984).

¹⁶⁵ Jacques E. C. Hymans, *The Psychology of Nuclear Proliferation: Identity, Emotions, and Foreign Policy* (Cambridge: Cambridge University Press, 2006).

accurately described as being comprised of a plurality of identities. At the root of his findings is the understanding that it takes a rare kind of leader—an “oppositional nationalist” as he terms it—to make the political decision to develop nuclear weapons.¹⁶⁶ As classified by Hymans, “oppositional nationalists define their nation as being both naturally at odds with and naturally equal (if not superior) to a particular external other.”¹⁶⁷ These leaders are highly predisposed to feeling fear and pride, both emotions that can lead to often irrational and seemingly malignant foreign policy decisions, such as deciding to illicitly pursue nuclear weapons.¹⁶⁸

Hymans’s approach to proliferation is important in the context of the purported nuclear revival because he addresses the element of prestige. There is a connection between pride in technological progress and pride in military strength, especially in the nexus between nuclear power and nuclear weapons, as discussed in chapter one. Hymans’s model does not directly bridge the gap between nuclear energy and nuclear weapons, but it nonetheless provides a practical way of doing so. Assessing how state leaders conceive of their national identities in the context of their decisions to pursue nuclear energy reveals a window through which we can view their likelihood of later turning that capability towards weapons development. According to Hymans’s logic, leaders that appear to be pursuing nuclear energy out of national pride are predisposed towards pursuing nuclear weapons as well.

¹⁶⁶ Hymans, 204.

¹⁶⁷ Hymans, 13.

¹⁶⁸ Hymans, 13.

Application of theory

A major part of the challenge in choosing which approach to proliferation is of the most merit is complicated by the fact that all approaches to proliferation are based on what Ogilvie-White calls the “nuclear myth”.¹⁶⁹ The utility or value of nuclear weapons is entirely a matter of perception and belief since their practical worth is unclear. These are, after all, weapons that states have stockpiled in large numbers without ever intending to use. Deterrence theory is a complicated and ambiguous endeavour, with various arguments both supporting and rejecting its effectiveness. Determining how possession of nuclear weapons translates into power—be it military or diplomatic—is not clear. These questions are beyond the scope of this paper, but are important in the construction of theories of why some states pursue nuclear weapons and others do not. Proliferation theories are therefore not only faced with trying to discern why states choose to go nuclear, but with the additional hurdle of figuring out what nuclear weapons mean to various states, groups and individuals.

There is no theory of proliferation to date that can accurately predict which states will pursue the bomb, and there will probably never be one due to the sheer number of variables involved and their dynamic nature as global circumstances change. The existing theories are nonetheless successful in identifying a number of root causes of proliferation as well as necessary, but not sufficient, conditions for it. In this regard they allow us to identify most likely proliferators in advance, even if a number of outstanding questions about a particular state going through with a nuclear weapons program remain. In chapter

¹⁶⁹ Ogilvie-White, 52.

four a number of indicators will be selected, drawn from the proliferation theories discussed above, to help identify which among the aspiring nuclear energy states may be predisposed towards pursuing nuclear weapons. Complicating the analysis further are the technical challenges that states inevitably face that can alter their course, as the following chapter discusses in depth.

Chapter 3 - The connection between nuclear energy and weapons

This chapter will consider what kind of scientific and institutional capability a peaceful nuclear energy program may or may not provide to a non-nuclear weapon state that might assist it in developing a nuclear explosive device.¹⁷⁰ The spread of peaceful nuclear energy capacities to new states—many would argue—goes hand in hand with the spread of latent capacities for developing nuclear explosive devices,¹⁷¹ since there is crossover of the scientific knowledge and technologies between them. Amory Lovins, L. Hunter Lovins and Leonard Ross, for example, argue that, “the collapse of nuclear power in response to the discipline of the marketplace is to be welcomed, for nuclear power is both the main driving force behind proliferation and the least effective way to displace oil.”¹⁷² This view of nuclear power is an extreme view, but the article is nonetheless indicative of the importance of understanding the role of nuclear power in nuclear proliferation. On the one hand, this chapter will demonstrate that a peaceful nuclear program provides a state with much of the technology, knowledge, expertise and infrastructure it requires to obtain fissile material for a nuclear device. On the other it will show that a peaceful nuclear program does not provide a state with much of the expertise or technology necessary to design and assemble a nuclear device. A peaceful nuclear program can put a country on the path towards having the technical competence to

¹⁷⁰ This chapter was previously published as: Justin Alger, “From Nuclear Energy to the Bomb: The Proliferation Potential of New Nuclear Energy Programs,” *Nuclear Energy Futures Paper No. 6*, (Waterloo: Centre for International Governance Innovation, September 2009).

¹⁷¹ For the purposes of this thesis a nuclear device refers specifically to a nuclear explosive device, and not other peaceful nuclear devices such as cancer therapy machines, food irradiators, smoke detectors, etc.

¹⁷² Amory B. Lovins, L. Hunter Lovins and Leonard Ross, “Nuclear Power and Nuclear Bombs,” *Foreign Affairs* 58:4 (1980): 1138.

construct a nuclear device, but does not allow it to overcome all obstacles to acquiring fissile material, nor does it provide the capability to weaponize and deliver a device.¹⁷³

A peaceful nuclear energy program for the purposes of this thesis refers to one in which a state operates at least one current generation power reactor. As such, it excludes the potential proliferation resistance of Generation IV reactors, which are next generation reactors not yet available. It does include turnkey operations in which the buying state does not have a major role in the design or construction of the reactor though typically has a role in operating the reactor. All new power reactors to be built in non-nuclear weapon states are assumed to be subject to IAEA safeguards since all are party to the NPT. A case in which a state builds a power reactor without IAEA safeguards is both unlikely and irrational on the part of the aspiring state.¹⁷⁴

First, this chapter will examine what a state can learn from a basic “once-through” nuclear program that could help it build a nuclear device. A once-through nuclear program uses natural uranium or low-enriched uranium (LEU) only once in a power reactor, thereby precluding any reprocessing of plutonium. The state is assumed to import LEU and has no capacity for enriching uranium. This type of program is typical of most state nuclear programs, and this is unlikely to change with future new entrants, in part due to the web of unilateral, bilateral and multilateral technology transfer restrictions¹⁷⁵

¹⁷³ For the purposes of this thesis, the ability of a state to detonate a nuclear device will be considered the point of concern for technical proliferation. Weaponization will not be addressed, although it is a challenging necessary step for a state trying to develop a fully deliverable nuclear arsenal. For more information about the challenges of weaponization see: “Technical Background: Nuclear Weapons Design and Materials,” *Nuclear Threat Initiative*, http://www.nti.org/e_research/cnwm/overview/technical2.asp, (accessed 7 January 2009).

¹⁷⁴ If a state wanted to build a reactor without IAEA safeguards, it would undoubtedly be a smaller, easier to hide plutonium production reactor and not a power reactor.

¹⁷⁵ Namely the Nuclear Suppliers Group, nuclear safeguards agreements and bilateral nuclear cooperation agreements.

designed to prevent the emergence of new enrichment and reprocessing states.¹⁷⁶ These once-through nuclear energy programs are expected to comprise the bulk of new nuclear build in the coming decades as a part of the purported nuclear revival.

Second, this chapter will clarify what enrichment or reprocessing technology can add to a state's ability to build a nuclear device. One of these technologies is required to produce the material for a nuclear device, so these technologies constitute an important step towards a state acquiring the technical capability to build one. Material acquisition is the major barrier to proliferation, so states that can cross this threshold have overcome the greatest obstacle to designing and building a nuclear device.¹⁷⁷

Third, the chapter will conclude by outlining what more is needed for a state that has access to enrichment or reprocessing to make the leap from nuclear energy to a nuclear device. Assembling a nuclear device can be technically difficult, requiring a different set of knowledge and expertise than that of a peaceful energy program, even if weapons material is available.

Once-through fuel cycle

A typical once-through fuel cycle involves a state owning and operating one or more nuclear power reactors fuelled by LEU and then discarding the spent fuel as waste after

¹⁷⁶ There are some exceptions. Brazil has recently started enrichment, while Argentina, South Africa and South Korea are exploring pyroprocessing, a form of reprocessing, though these are far from established programs. Argentina is also pursuing its own gaseous diffusion enrichment capability.

¹⁷⁷ In some cases it may be possible for a state to skip this step by attaining the material elsewhere, such as using HEU supplied for a research reactor, but these too are under safeguards and are gradually being converted to use LEU instead.

its first use.¹⁷⁸ LEU in these cases is typically supplied by a select few advanced nuclear states with enrichment capabilities.¹⁷⁹ The major nonproliferation benefit of most once-through fuel cycles is that the operating state does not come into direct contact with weapons grade material—high-enriched uranium (HEU) or plutonium—or the technology to acquire it at any stage since the supply of LEU from just a few suppliers has historically outstripped demand.¹⁸⁰ The technical proliferation involved in a once-through fuel cycle will be discussed here.

Scientific expertise and fissile material

Both nuclear reactors and nuclear bombs use either uranium or plutonium to create a nuclear chain reaction that releases energy. The speed with which they release energy is the crucial difference between the two: in a reactor the energy release is controlled and sustained over an extended period, whereas in a nuclear bomb the release occurs in fractions of a second. The science of fission is fairly straightforward, and it is controlling fission reactions to get a desired effect that is challenging.¹⁸¹ A fission reaction is induced by introducing neutrons into certain isotopes of uranium or plutonium atoms¹⁸², thereby causing them to become unstable and split into lighter atoms. These lighter atoms do not equal the mass of the initial atom, and in the process this lost mass is converted into

¹⁷⁸ The vast majority of reactors are light water reactors (LWR) that use LEU. There are a small number of heavy water reactors that use natural uranium as fuel. They are able to use natural uranium because heavy water has a low affinity for neutrons, thus increasing the availability of neutrons for fission reactions.

¹⁷⁹ Those currently producing enriched uranium are China, France, Germany, Iran, Japan, Netherlands, Pakistan, Russia, the United Kingdom and the United States: Nuclear Energy Agency, 57.

¹⁸⁰ Clarence Hardy, "The Case for Uranium Enrichment in Australia," World Nuclear Fuel Cycle 2009, World Nuclear Association, 22 April 2009.

¹⁸¹ Mozley.

¹⁸² U-235, U-233 and Pu-239 all become unstable when a neutron is introduced. Natural uranium contains 99.284% U-238, 0.0058% U-234 and only 0.711% of the fissionable U-235, hence the need for enrichment technology to increase the level of U-235. Plutonium does not occur in nature, hence the need for reprocessing. See: Robert F Mozley, *The Politics and Technology of Nuclear Proliferation*, (University of Washington Press: Seattle and London, 1998), 21-42 for more.

energy, as per Albert Einstein's famous $E=mc^2$ formula.¹⁸³ Nuclear reactors and explosives both harness the energy produced by fission, but this basic understanding does little to reveal the relationship between the two.

A different set of scientific knowledge and engineering prowess is needed for designing and manufacturing a nuclear reactor and a nuclear device, only some of which is interchangeable. To develop a nuclear device, the speed of the chain reaction creates additional requirements for the firing mechanism, the grade of the uranium or plutonium used, and the density, physical surrounding and shape of the fissile material.¹⁸⁴ These differences are substantial barriers for a state looking to shift from power production to producing a nuclear device. Controlling the flow of neutrons in a power reactor arguably requires more sophisticated technology than that required for a basic nuclear weapon, but the important point is that the technologies are essentially different and require a different set of knowledge and expertise.¹⁸⁵ The benefits in terms of knowledge and expertise that states gain in operating a power reactor makes state acquisition of a nuclear device easier.

There is a large amount of crossover between peaceful and military disciplines of scientific study in the nuclear field. The majority of these disciplines are specific to design and operation of a nuclear reactor or to enrichment and reprocessing techniques. Scientific disciplines in which this crossover exists are the following¹⁸⁶:

¹⁸³ Einstein's formula gives the fundamental relationship between mass and energy. In prose, energy (E) is equal to the square of the product of mass (m) and the speed of light (a constant 'c').

¹⁸⁴ See: International Physicians for the Prevention of Nuclear War, 1996 publication: pgs.ca/wp-content/uploads/2008/06/nukes-advanced-physics.ppt). For information on the "cross section" of a nuclear chain reaction see: Mozley, 32-36.

¹⁸⁵ See: Mozley, 23-25, 44-46.

¹⁸⁶ Comptroller General of the United States, "Difficulties in Determining If Nuclear Training Of Foreigners Contributes To Weapons Proliferation," *United States General Accounting Office*, 23 April 1979.

- Nuclear engineering
- Chemical engineering
- Metallurgical engineering
- Mechanical engineering
- Electrical engineering
- Physics
- Mathematics and computer science
- Chemistry

Examples of peaceful-military crossover in nuclear engineering would be calculating fissile atom depletion and production, criticality calculations and the design of nuclear reactors.¹⁸⁷ A detailed—and highly technical—list of the crossover is available in a 1979 Report by the Comptroller General of the United States titled *Difficulties in Determining If Nuclear Training Of Foreigners Contributes to Weapons Proliferation*.¹⁸⁸ There is a substantial amount of overlap between civilian and military nuclear applications, but there is little a state could gain from a peaceful program specific to designing and assembling a nuclear device. Some of this overlap—particularly chemical engineering—is specific to sensitive fuel cycle technologies and an understanding of these areas is not typical of most nuclear energy programs, as evidenced by the relatively few states that possess them (9 enrichment states and 3 reprocessing states). What a once-through peaceful program nonetheless does provide is the scientific foundation upon which a state can go on to build and operate its own dedicated plutonium production reactor for a bomb program. A dedicated reactor is ideal for a weapons program using plutonium because of some of the challenges associated with using reactor grade material for a nuclear device and the difficulty of circumventing IAEA safeguards, designed to prevent the diversion of material and facilities from peaceful to military purposes.¹⁸⁹

¹⁸⁷ Comptroller General of the United States.

¹⁸⁸ Comptroller General of the United States.

¹⁸⁹ All new power reactors that are not located in one of the five official or four unofficial nuclear weapon states (including North Korea) is required to be under safeguards. A state can, of course, build a

Neither LEU feedstock nor the plutonium contained in the spent fuel from a power reactor is ideal for building a first nuclear weapon.¹⁹⁰ To fully illustrate that point, there has never been an instance of a state diverting power reactor-grade material (uranium or plutonium) to use in a nuclear device. Using reactor grade material in a nuclear device is possible in some cases, but the technological sophistication involved limits this possibility to the most advanced states.¹⁹¹ Uranium ideally needs to be enriched to 90 percent or higher U-235 to be considered weapons grade, compared with the 3 to 5 percent used in most light-water reactors (LWRs).¹⁹² With low enrichment levels the amount of material needed for the device to reach criticality is so large that the device could not realistically be detonated, particularly at enrichment levels below 20 percent.¹⁹³ Nuclear devices using material with lower enrichment levels have been built by advanced weapons laboratories¹⁹⁴, but even in these cases the enrichment level is more in the realm of 20 percent rather than 3 to 5 percent.¹⁹⁵ The IAEA therefore considers uranium with 20 percent or higher U-235 to be high-enriched uranium, and the minimum enrichment level required for a crude nuclear device.¹⁹⁶

clandestine reactor, but in this case the state is almost assuredly going to build a dedicated production reactor and not a power reactor for pragmatic reasons.

¹⁹⁰ Weapons grade material can technically be used as reactor fuel, but there is no legitimate incentive to do so. The exceptions to this are global initiatives such as the Global Partnership Program to reduce stockpiles of weapons grade plutonium by burning the material in power reactors, particularly stockpiles from the former Soviet Union.

¹⁹¹ See: Victor Gilinsky et al., "A Fresh Examination of the Proliferation Dangers of Light Water Reactors," The Nonproliferation Policy Education Center, 22 October 2004.

¹⁹² Uranium weapons can be made using 20 to 90 percent enriched uranium, but the complexity and practicality of doing so drops dramatically along with the enrichment level. The bomb dropped by the US on Hiroshima in 1945 was, nonetheless, of 80 percent enriched uranium.

¹⁹³ Global Fissile Material Report 2008, *International Panel on Fissile Materials*, http://www.fissilematerials.org/ipfm/site_down/gfmr08.pdf, 105-106.

¹⁹⁴ It is also difficult to predict the yield of a device with lower enrichment levels but this may not be much of a concern to a state pursuing one.

¹⁹⁵ Global Cleanout of Weapons Usable Nuclear Materials, *The Henry L. Stimson Center*, May 2007, <http://www.stimson.org/cnp/?SN=CT200705211264> (accessed 9 September 2009).

¹⁹⁶ Global Fissile Material Report 2008, 106.

Reprocessed spent power reactor fuel, regardless of the type of feedstock, is not an ideal source of plutonium for a nuclear device due to the high occurrence of Pu-240, an isotope of plutonium that has a high rate of spontaneous fission. Pu-239 is the desirable isotope of plutonium for a controlled fission process and its occurrence is highest when the fuel is left in the reactor for a relatively short time. The longer the initial fuel is left in the reactor the higher the occurrence of Pu-240, as is the case with power reactor fuel. Given the longer time that power reactor fuel stays in the reactor the Pu-240 build-up is high. It is, however, possible to use reprocessed power reactor fuel high in Pu-240 for an implosion device. Despite long-held beliefs to the contrary, the US National Academy of Sciences and US Department of Energy reached this conclusion in the 1990s:

*Virtually any combination of plutonium isotopes...can be used to make a nuclear weapon. In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapons states.*¹⁹⁷

Plutonium from any reactor therefore does pose a diversion risk. Reprocessed plutonium is not typically used as reactor fuel¹⁹⁸ for economic reasons but there are initiatives to change this such as mixed-oxide (MOX)-fuelled or fast breeder reactors.¹⁹⁹

Operating a power reactor does not provide a state with access to weapons material on the front or back end without an enrichment or reprocessing facility, and in the case of a plutonium device without the additional task of building a plutonium production reactor or diverting material from a power reactor. The ease with which a state can convert a

¹⁹⁷ Originally quoted in: H.A. Feiveson, "Nuclear Proliferation and Diversion," *Encyclopedia of Energy*, Vol. 4, 2004, 436.

¹⁹⁸ Every reactor in operation today derives between a third and a half of its energy output from plutonium that is produced in-situ during normal operation: Private e-mail exchange with Atomic Energy of Canada Limited (AECL) employee, September 2008.

¹⁹⁹ Mixed-oxide fuel (MOX) blends plutonium with uranium and is an exception. Only a few advanced nuclear countries have produced MOX and the economics of it are questionable, so it is not widely distributed. MOX is not weapons ready material but according to the IAEA isolating the plutonium is fairly simple.

power reactor to producing weapons-grade material is dependent on the type of reactor.²⁰⁰ A LWR can be used to produce the desirable Pu-239 simply by reducing the length of time the fuel spends in the core, however the amount of fuel required to do so is staggeringly large and a clear signal that the state is using the reactor to produce plutonium if the facility is under safeguards.²⁰¹ The same is true of a commercial heavy water reactor (HWR).²⁰² The perceived main benefit of using a HWR to produce plutonium is that it does not need to be shut down to refuel. This perception is inaccurate, however, since a current HWR could not be refueled nearly fast enough to function as a production reactor. Misusing power reactors to produce plutonium is not technically difficult since not much needs to be done, but the state would then need to circumvent IAEA safeguards to do so, which would raise alarm bells immediately. A misused power reactor would also be far less efficient than a dedicated production reactor.²⁰³

Learning how to handle radioactive material is another benefit of a once-through nuclear program. The longer that fissile material stays in a reactor—ideally long for a power reactor due to the desire to maintain a constant fission process—the greater the concentration of highly radioactive fission products and transuranic elements.²⁰⁴ The radioactivity of the material from a power reactor is therefore several magnitudes higher than that of material produced in a dedicated plutonium production or research reactor. All of the techniques involved in handling radioactive material from a dedicated plutonium production reactor can thus be learned by operating a power reactor, at least up

²⁰⁰ See: Gilinsky et al., 24-31.

²⁰¹ Private e-mail exchange with Atomic Energy of Canada Limited (AECL) employee, September 2008.

²⁰² Private e-mail exchange with Atomic Energy of Canada Limited (AECL) employee, September 2008.

²⁰³ Private e-mail exchange with Atomic Energy of Canada Limited (AECL) employee, September 2008.

²⁰⁴ “Radioactive Waste”, *Health, Environment and Safety*, chapter 8, 246.

until the reprocessing stage.²⁰⁵ Techniques for handling radiation learned from an energy program can therefore be useful in the plutonium path to the bomb²⁰⁶, although the challenges posed by radiation can be bypassed entirely by enriching uranium instead.

Infrastructure and Personnel

The main benefit derived from a once-through nuclear energy program towards the construction of a nuclear device is building up a nuclear infrastructure that would otherwise be difficult if not impossible to camouflage. States can, and have, used technical assistance and training provided by advanced nuclear states and the IAEA—justified on the basis of their nuclear power generation needs—to enhance their potential nuclear weapons capability. India, Israel, North Korea, Pakistan and South Africa all used some degree of peaceful assistance from advanced nuclear states to assist in their eventual weapons program.²⁰⁷ An energy program provides a state with a starting point for acquiring the technology and expertise that it would need to produce the material for a nuclear device. The Nuclear Suppliers Group (NSG) has established a lengthy list of dozens of technologies and materials that are dual-use in nature, and can be used for either peaceful or weapons purposes.²⁰⁸ Export of these items is controlled by the NSG, but the size of the list reveals that much of the equipment and components a state needs to produce a weapon can be acquired under the guise of peaceful applications.

²⁰⁵ Mozley, 56-63.

²⁰⁶ Although the basic techniques remain the same, there are added challenges in handling the radioactivity involved in acquiring plutonium. A more detailed assessment of these challenges will be included later in the chapter.

²⁰⁷ See the Nuclear Threat Initiative's country profiles for detailed historical overviews of the roots of these countries' nuclear programs: "Country Profiles," *Nuclear Threat Initiative*, http://www.nti.org/e_research/profiles/index.html (accessed 9 September 2009).

²⁰⁸ International Atomic Energy Agency, "Communications Received from Certain Member States Regarding Guidelines for Transfers of Nuclear-related Dual-use Equipment, Materials, Software and Related Technology" INFCIRC/254/Rev.7/Part 2^a, 20 March 2006, <http://www.nuclearsuppliersgroup.org/Leng/PDF/infirc254r7p2-060320.pdf> (accessed 9 September 2009).

There is no mathematical way to express how important a peaceful nuclear energy program could be for eventual weapons development, but the evidence suggests that it is critical, particularly in developing states that lack adequate institutions for higher learning. In a conversation with George Perkovich, Munir Ahmen Kahn, former leader of Pakistan's nuclear program, said:

*The Pakistani education system is so poor, I have no place from which to draw talented scientists and engineers to work in our nuclear establishment. We don't have a training system for the kind of cadres we need. But, if we can get France or somebody else to come and create a broad nuclear infrastructure, and build these plants and these laboratories, I will train hundreds of my people in ways that otherwise they would never be able to be trained. And with that training, and with the blueprints and the other things we'd get along the way, then we could set up separate plants that would not be under safeguards, that would not be built with direct foreign assistance, but I would now have the people who could do that. If I don't get the cooperation, I can't train the people to run a weapons program.*²⁰⁹

Pakistan was highly dependent on outside knowledge and assistance in order to eventually build a nuclear device. India likewise received training and technology from the US and Canada, including a research reactor that was used to produce the material for India's 1974 nuclear test. France supported Israel's nuclear program by providing technology and equipment during the 1950s that led to the eventual development of the Israeli nuclear bomb.²¹⁰ North Korea received assistance from the Soviet Union, including a research reactor, and was later allegedly supplied by Pakistan to allow for its

²⁰⁹ George Perkovich, "Nuclear Power in India, Pakistan and Iran," in *Nuclear Power and the Spread of Nuclear Weapons: Can We Have One without the Other?*, eds. Paul Leventhal et al, (Brassey's: Washington D.C., 2002), 194.

²¹⁰ In Israel's case it did not bother to continue with its peaceful nuclear energy program and diverted all of its resources to weapons development. See: Matthew Kroenig, "Exporting the Bomb: Why States Provide Sensitive Nuclear Assistance," in *American Political Science Review*, vol. 103, no. 1 (February 2009).

eventual detonation of a nuclear device in 2006.²¹¹ South Africa received a research reactor and high-enriched uranium to fuel it from the United States that became the genesis of its nuclear program.²¹² Every case of successful nuclear weapons development since the NPT came into force in 1970 was done under the guise of a peaceful nuclear program with the assistance of nuclear supplier states.

Most transfers of nuclear power technology, however, do not involve sensitive fuel cycle technology. Importing reactors and the knowledge to build and operate them is not sufficient for a state to move directly into weapons development. At some point the state needs to acquire an independent enrichment or reprocessing capability or obtain weapons grade fissile material from some other source. Pakistan, Israel and North Korea all had the benefit of assistance with sensitive fuel cycle technologies from a nuclear supplier.²¹³ India, on the other hand, used the nuclear technology and expertise it gained from assistance from the US and Canada prior to 1974 to autonomously develop a reprocessing capability.²¹⁴ The Indian and South African cases demonstrate that even without direct assistance with enrichment or reprocessing technology a state can use an otherwise peaceful nuclear infrastructure to simplify its path towards a nuclear device. The scientific knowledge and expertise and infrastructure needed for a peaceful nuclear energy program can serve as an opening through which a state can cross the threshold

²¹¹ Nuclear Threat Initiative, “North Korea Profile – Nuclear,” http://www.nti.org/e_research/profiles/NK/Nuclear/index.html (accessed 30 March 2009).

²¹² Nuclear Threat Initiative, “Country Profile – South Africa,” http://www.nti.org/e_research/profiles/SAfrica/index.html (accessed 11 September 2009).

²¹³ Pakistan had help from France in building the Chasma and Pinstech reprocessing plants, and it is suspected China helped Pakistan with the Kahuta enrichment plant. Israel had assistance, also from France, in constructing the Dimona reprocessing plant. North Korea received reprocessing technology from the Soviet Union in the 1960s, and is suspected of having received designs and components for an enrichment plant from Pakistan. For further details see: Kroenig and “North Korea Profile – Nuclear,” Nuclear Threat Initiative, http://www.nti.org/e_research/profiles/NK/Nuclear/index.html (accessed 30 March 2009).

²¹⁴ See: George Perkovich, *India’s Nuclear Bomb: The Impact on Global Proliferation*, (University of California Press: Berkley, 1999).

into developing enrichment and reprocessing technologies. In the context of latent proliferation, a peaceful nuclear energy program is therefore best characterized as a stepping stone towards acquiring the wherewithal for a nuclear device. The program alone is ultimately insufficient for gaining all of the technology and expertise required.

Training foreign scientists in nuclear engineering and related fields may in some cases pose proliferation risks, but advanced nuclear states have either voluntarily or in accordance with international agreements undertaken to provide it. Bilateral assistance efforts, beginning with the US ‘Atoms for Peace’ program in the 1950s, the statute of the International Atomic Energy Agency, and Article IV²¹⁵ of the NPT have all encouraged the global spread of nuclear expertise for peaceful purposes. Both the IAEA and member states provide training seminars, workshops and other technical assistance to states that request it.²¹⁶ Training in sensitive fuel cycle technologies has declined since the 1960s as a result of proliferation concerns,²¹⁷ but nuclear training nonetheless continues. A declassified report by the Comptroller General of the United States characterizes the problem with limiting training programs to avoid providing sensitive nuclear expertise as follows:

*Department of Energy officials said that sensitive areas of nuclear technology have been examined and precautions have been taken, but it is difficult to draw a firm line between what is and is not sensitive; it is a matter of degree.*²¹⁸

²¹⁵ Article VI states that “Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.”

²¹⁶ At least two dozen states provide various degrees of nuclear training. See: Report by the Comptroller General of the United States.

²¹⁷ For example, during the 1960s and 1970s, the US government allowed a few dozen foreign scientists to be involved in unclassified research relating to enrichment or reprocessing. See: Report by the Comptroller General of the United States, i.

²¹⁸ Comptroller General of the United States, vi.

Training programs provided by the IAEA and member states are educating foreign scientists in fields that are necessary—though not sufficient—for them to understand how to be able to design and construct a nuclear device or replicate sensitive technologies such as enrichment or reprocessing. These training programs can and have contributed to proliferation, but the pertinent question is one of the motivation and the intention of the scientists being trained. Newly trained nuclear scientists and engineers are the largest proliferation concern arising from a peaceful nuclear energy program because they have the capability to expand their activities to include more sensitive, weapons applications.

Sensitive fuel cycle technology

Enrichment and reprocessing plants are referred to as sensitive because a state that has access to either can produce weapons grade material for a nuclear device. Enrichment and reprocessing technology can be used to produce fissile material whether it is destined for a power reactor or a weapon, although there are differences, albeit mostly inconsequential, in how the technology is used to do so. The acquisition of one of these two technologies marks a major leap forward for a state intent on developing a nuclear device. Perhaps the greatest risk of the nuclear revival in terms of capacity to produce nuclear weapons is the potential for new states to acquire enrichment and reprocessing technology justified as being for peaceful purposes as Iran has.

Enrichment

Nearly all of the world's power reactors use low-enriched uranium (LEU) as fuel. There are exceptions to this, the main one being a small number of reactors manufactured by Canada and India that are moderated by heavy water and use natural uranium as fuel,

as well as old British gas-graphite reactors used mainly in the UK.²¹⁹ There are relatively few non-nuclear weapon states—Argentina, Brazil, Germany, Iran, Japan and the Netherlands—with a domestic enrichment capability and among them only Iran is currently considered at risk of using it for weapons purposes.²²⁰ Those states with nuclear reactors that do not enrich domestically import LEU from a major supplier, often France, Russia, the US or URENCO, jointly owned by Germany, the Netherlands and the UK. From 2004 until recently there was a G-8²²¹ moratorium on exporting enrichment (and reprocessing) technology to new states, but the group chose not to extend it in 2009. Instead it has taken the softer approach of encouraging its members to avoid transferring certain techniques and technologies in a way that would enable their reproduction, notably the United States' ongoing efforts to work through the Nuclear Suppliers Group to establish strict criteria for such transfers.²²² The likelihood of new enrichment states emerging in the short-term is nevertheless relatively low. The essential point, however, is that as long as power reactors use enriched fuel and states are legally permitted to have the full nuclear fuel cycle, albeit providing it is under safeguards, it will be the sovereign right of states to enrich uranium should they choose to. Therefore the possibility of new enrichment states will continue to exist.

²¹⁹ The abundance of neutrons in heavy water allows for the use of natural uranium because it reduces the neutron generation required by the fission process itself, thereby circumventing the requirement for higher U-235 levels in most reactors. The biggest downside of heavy water moderated reactors is economic: heavy water is expensive to produce and the initial capital outlay of these plants is relatively high.

²²⁰ China, France, India, North Korea, Pakistan, Russia, UK and US have enrichment plants as well as nuclear weapons already. Brazil, Germany, Japan, Iran and the Netherlands have enrichment plants, and aside from Iran, have long chosen to forego acquiring their own nuclear weapons.

²²¹ The "Group of 8" refers to an informal forum of the eight wealthiest countries in the northern hemisphere in order to cooperate on addressing some of the major challenges facing the world. Its membership includes Canada, France, Germany, Italy, Japan, Russia, the UK and the US.

²²² Miles Pomper and Wade Boese, "Efforts to Limit Fuel Cycle Capabilities Falter," *Arms Control Today*, http://www.armscontrol.org/act/2008_09/FuelCycle, September 2008.

A state with an enrichment facility can without difficulty produce the material for a nuclear device.²²³ The difference between producing LEU and HEU is mainly one of how many times the material is put through the centrifuges in “batch” enrichment.²²⁴ Otherwise the centrifuges can be reconfigured for HEU production.²²⁵ Roughly two-thirds of the enrichment required to produce HEU has already been done if a state begins the process with LEU.²²⁶ This means that the volume of material required is significantly less if a state has access to LEU, reducing the chance of being caught if being done clandestinely. The difference in starting the enrichment process with LEU rather than natural uranium is, however, more a matter of time than ability. In terms of scientific and technical capability, the enrichment level of the uranium a state starts the enrichment process with is a moot point. Once a state has an enrichment facility it is capable of producing weapons grade material.

Obtaining enrichment technology generally requires the assistance of a nuclear supplier. Enrichment technologies are closely controlled by the countries that own them, so an aspiring enrichment state would generally need to make a compelling case to a supplier state and the Nuclear Suppliers Group to obtain them. The technology is closely controlled enough that even a champion of nonproliferation like Canada was unable to

²²³ Although enrichment can also be done through gaseous diffusion, chemically, electromagnetically or with lasers, centrifuge technology is the most cost effective and most common technology used today. The US still uses gaseous diffusion. Some advanced nuclear states are exploring alternative enrichment technologies. See: “Box 3: Uranium Enrichment: Inputs and Outputs,” Nuclear Threat Initiative, http://www.nti.org/e_research/cnwm/overvie-w/techbox_3.html.

²²⁴ David Albright and Jacqueline Shire, “A Witches’ Brew? Evaluating Iran’s Uranium-Enrichment Progress,” *Arms Control Today*, http://www.armscontrol.org/act/2007_11/Albright, November 2007.

²²⁵ Either batch recycling or reconfiguring the centrifuges for HEU production are not prohibitively difficult for a state already successfully operating them. See: Albright and Shire.

²²⁶ Although the gap between 3 and 90 percent enriched uranium sounds large, a substantially larger amount of natural uranium would be required to produce HEU than if a state were starting the process with LEU. See: Mozley, chapter 4, “Uranium Enrichment.”

persuade the US to provide it with enrichment technology that was not black-boxed.²²⁷ The other alternative is to acquire designs and equipment through possible clandestine networks, though since the uncovering of the AQ Khan network this may not be an option. It is also possible for a state to develop an indigenous capability over time—as Argentina, Brazil and South Africa for the most part did—though it would still be dependent on its scientists receiving the necessary training and expertise. The size and electric power requirements of enrichment facilities were typically large enough that it would be difficult for a state to clandestinely develop them, even if it were able to obtain illicit assistance, but modern facilities are smaller and more difficult to detect.²²⁸ The proliferation risk with enrichment facilities is nonetheless closely intertwined with the willingness of current enrichment states to provide necessary design information as well as access to certain parts and equipment. The emphasis of the nonproliferation regime has, as a result, been on limiting the supply of enrichment technology. These supply limitations are a large part of why it would be difficult for a newcomer state to enrich its own uranium for a nuclear device, although it is certainly possible, as the Iranian example indicates.

Reprocessing

Reprocessing of reactor spent fuel (or waste) to produce plutonium is not generally considered an economically viable way of obtaining fuel for civilian power reactors, but has historically been the path of choice towards a nuclear device for most states. The first nuclear tests conducted by the US, the Soviet Union, the UK, France, India and North

²²⁷ The NSG is in the process of determining criteria for such transfers. See: Miles Pomper, “Nuclear Suppliers Make Progress on New Rules,” *Arms Control Today*, http://www.armscontrol.org/act/2008_12/NSG_progress, December 2008.

²²⁸ For more information about the difficulty in concealing and powering enrichment facilities, see: Mozley, 124-125.

Korea all used plutonium from a dedicated production or research reactor, and Israel's untested arsenal is presumed to be of plutonium weapons as well.²²⁹ This is the case despite plutonium weapons being more difficult to design than gun-type uranium weapons. Only China and Pakistan detonated a uranium weapon first, and South Africa's untested weapons were also of uranium.²³⁰ The plutonium isotope Pu-240 produces a massive amount of neutrons when it undergoes spontaneous fission, inevitably causing a poorly designed nuclear device to detonate prematurely or 'fizzle.'²³¹ This creates challenges in design that would seemingly lead to the conclusion that a uranium device would be easier for states to pursue first. Pakistan, in fact, gave up trying to design a plutonium device because it was too complicated.²³² The reason states have historically chosen the plutonium path to the bomb instead is because reprocessing technology, although still complex, is simpler to master than enrichment technology.

For a determined state, reprocessing is difficult though not prohibitively so. For an emerging nuclear country, the challenge with reprocessing technology is not the chemical separation process but handling the highly radioactive byproducts of reactor operation and plutonium separation.²³³ A reprocessing plant needs to handle millions of curies of fission products in the form of highly concentrated solutions and vapours.²³⁴ The

²²⁹ The US assembled a uranium device before a plutonium one, but Manhattan Project scientists were so confident in their uranium weapon that they decided not to bother testing it before deploying one over Hiroshima, so the US example is technically accurate but fails to make the point. See: Mozley, 43.

²³⁰ Nuclear Threat Initiative, "South Africa Profile - Nuclear Overview," http://www.nti.org/e_research/profiles/SAfrica/Nuclear/index.html (accessed 11 November 2009).

²³¹ Jeremy Bernstein, *Nuclear Weapons: What You Need to Know* (New York: Cambridge University Press, 2008), 139-140.

²³² Nuclear Threat Initiative, "Nuclear Chronology - Pakistan," http://www.nti.org/e_research/profiles/Pakistan/Nuclear/5593_6387.html (accessed 11 September 2009).

²³³ Mozley, 56-63.

²³⁴ S. Krishnamony et al., "Monitoring of the Working Environment in a Fuel Reprocessing Plant," in *Radiation Protection Monitoring* (Vienna: International Atomic Energy Agency, 1969), 253.

‘availability’²³⁵ of radiation in these solutions and vapours is substantially higher than that of once-through reactor fuel. Whereas in a power reactor the highly radioactive fission products are contained within the fuel element, in a reprocessing plant they are extracted and need to be handled directly.²³⁶ A state without an existing commercial reprocessing capability would need to acquire or develop the technology and techniques to handle the additional radiation challenges if it wanted to use plutonium for a bomb.

Any conventional reprocessing facility is dual use in nature and can be used to extract plutonium for civilian or military use. The difference in the chemical composition of the byproducts that result from reprocessing spent fuel from a power reactor versus that from a production reactor is negligible in terms of the handling and storage techniques required.²³⁷ France, for example, stores most of its military and civilian reprocessing byproducts in the same locations, handled by the same company, in exactly the same manner.²³⁸ Reprocessing any spent fuel creates a number of different waste streams that a state would not encounter in a once-through power program, leading to a higher volume of waste and a much “hotter” or higher density level of radioactivity.²³⁹ The more important consideration is how concerned a state clandestinely pursuing nuclear weapons would be about protecting workers, the public and the environment from the hazards of reprocessing byproducts. Given that the greatest challenges in handling radioactivity resulting from reprocessing occur only after the plutonium has been extracted, this can probably be considered a moot point. Avoiding detection by the IAEA or other interested

²³⁵ Radiation availability refers to the degree to which radioactive elements are exposed to their external environments. In the case of nuclear, radiation is less available when contained in the spent fuel element.

²³⁶ S. Krishnamony et al., 253.

²³⁷ S. Krishnamony et al., 250-252.

²³⁸ Mary D. Davis, *The Military-Civilian Nuclear Link: A Guide to the French Nuclear Industry*, (London: Westview Press, 1988).

²³⁹ Robert Vandenbosch and Susanne E. Vandenbosch, *Nuclear Waste Stalemate: Political and Scientific Controversies*, (Salt Lake City: University of Utah Press, 2007), 15-21.

parties, especially using increasingly powerful wide-area environmental sampling techniques, is another challenge facing a potential proliferator.

Handling reprocessing radioactivity is significantly easier if a dedicated production reactor instead of a power reactor is used to produce plutonium. According to the US Department of Energy (DOE), to reprocess spent power reactor fuel involves handling about 25 times the amount of radioactivity as handling the spent fuel from a dedicated weapons production reactor.²⁴⁰ The implication is that a state with a nuclear energy program involving a reprocessing capability is overqualified to handle radioactivity in reprocessing weapons grade material.

Difficulty of acquiring enrichment or reprocessing technology

India and South Africa were both able to develop indigenous reprocessing and enrichment capabilities respectively with minimal outside help. Minimal outside help means that there was little direct transfer of sensitive fuel cycle technology designs or equipment. Both states were, however, operating within an international climate in which they had several advantages over states at similar stages of development today. They were among the main beneficiaries of development initiatives that encouraged technical assistance and foreign aid, including a wide range of nuclear technologies.²⁴¹ Until India's nuclear test in 1974 the advanced nuclear states were also somewhat lax about restricting access to training and assistance in sensitive areas of nuclear technology, including enrichment and reprocessing.²⁴² Indian and South African scientists had access to more outside training and expertise than their counterparts would now. Furthermore, nuclear

²⁴⁰ Bob Alvarez, "Reprocessing spent nuclear fuel too risky," *The Columbus Dispatch*, 15 November 2008.

²⁴¹ See: Joseph Pilat, *Atoms for Peace: A Future after Fifty Years?* (Woodrow Wilson Center Press, Washington and The Johns Hopkins University Press, Baltimore, 2007).

²⁴² See: Comptroller General of the United States.

export controls and safeguards were still rudimentary in the 1960s and 1970s, so it would have been easier to obtain equipment and components and to build facilities without attracting international attention. The advanced nuclear states and the nonproliferation regime generally have learnt from mistakes of the past. The relative ease with which Indian and South African scientists indigenously developed sensitive fuel cycle technology is not likely to be replicated anytime soon.²⁴³

Sensitive fuel cycle technology is difficult for states to obtain today for political reasons. The proliferation risks associated with it are now well appreciated, so nuclear suppliers have taken steps to limit its dissemination. Beyond the US and NSG efforts already discussed, there is also a number of ongoing initiatives to discourage states from wanting either technology, including but not limited to the IAEA's multilateral fuel bank initiative and the joint Russian-Kazakh Angarsk enrichment facility.²⁴⁴ Certain players within the global nonproliferation regime are pushing for closing the gap in the NPT whereby a state can acquire much of the technology and expertise it needs for a weapons program, especially sensitive fuel cycle technology, and then withdraw from the treaty to pursue a nuclear device, such as North Korea did in the 1990s. The regime is targeting enrichment and reprocessing technology since without one of the two states cannot produce the material for a nuclear weapon.

Pakistani scientist Abdul Qadeer Khan was able to circumvent nonproliferation measures in place at the time, eventually setting up a black market for nuclear blueprints,

²⁴³ Iran benefited immensely from enrichment design information it obtained from Pakistan through the AQ Khan network. See: Nuclear Threat Initiative, "Nuclear Overview – Iran," http://www.nti.org/e_research/profiles/Iran/Nuclear/index.html (accessed 11 September 2009).

²⁴⁴ The US-led Global Nuclear Energy Partnership (GNEP) was potential helpful but the Obama administration has ended the program domestically and is likely to considerably recast its international aspects. For a detailed assessment of GNEP see: Miles Pomper, "US International Nuclear Energy Policy: Change and Continuity," *Nuclear Energy Futures Paper*, Centre for International Governance Innovation (forthcoming 2009).

equipment and materials. Khan worked for URENCO at an enrichment plant for several years. He then used the training he received and the blueprints he stole to spearhead an enrichment program in Pakistan ultimately leading to Pakistan's acquisition of the atomic bomb. Through the black market he set up he provided Iran, Libya and North Korea with various degrees of illicit nuclear assistance, including blueprints for Iran's ongoing enrichment program.²⁴⁵ While sensitive fuel cycle technology is difficult to acquire through legitimate channels, there are alternatives if a privileged scientist can be persuaded to assist a state illicitly. That states would need to resort to stealing blueprints or buying them on the black market is, however, a testament to how difficult it is to develop enrichment or reprocessing facilities without outside assistance.

Developing a nuclear device

A peaceful nuclear program does not provide a state with the technology to design and build a nuclear explosive device. In order for a state to do so, it will need to learn, among other things, how to construct explosive lenses²⁴⁶, construct an electrical firing system that is accurate to a fraction of a microsecond and build a triggered neutron source to assure a source of neutrons to ignite a chain reaction at the time of firing.²⁴⁷ Weaponization activities additionally include computer simulations, modeling and calculations, high-energy electrical components and implosion testing, as well as acquiring certain non-nuclear materials such as beryllium, polonium, tritium and

²⁴⁵ For a more detailed account of Khan's history see: David Albright and Corey Hinderstein, 'Unraveling the A.Q. Khan and future proliferation networks', *Washington Quarterly*, Spring 2005.

²⁴⁶ For an implosion type assembly.

²⁴⁷ Mozley, 24.

gallium.²⁴⁸ While the designs for these technologies are not readily available in the public domain, they can be acquired by a determined state. For example, Indian and Pakistani scientists were without suspicion or great difficulty able to learn how to develop neutron initiators in French and Chinese laboratories respectively²⁴⁹, though this may not be as easy for a state to do now, given a more robust and encompassing nonproliferation regime.

The shape that the fissile material is molded into determines the ease with which the material can reach critical mass. Depending on the type of nuclear weapon, a spherical or hemispherical shape is the most common.²⁵⁰ Fissile material is typically converted into a metal before being used in a nuclear device. The other alternative—using oxides without conversion to metal—requires more material and has other disadvantages in bringing the material into an explosive configuration, the end result being a so-called “crude nuclear device.”²⁵¹ Oxides in the nuclear context refer to the chemical compounds UO_2 and PuO_2 which contain either uranium or plutonium combined with oxygen to make weapons-usable material in a powder and solid form respectively.²⁵² Casting and machining fissile material into the required shape for a nuclear device is not complicated conceptually, but it would be difficult and time consuming to put into practice unless experienced scientists were involved.²⁵³ Much of this experience can be gained through working with fissile

²⁴⁸ Some of these activities are unique to implosion designs. See: John Carlson et al., *Nuclear Weaponisation Activities: What is the Role of IAEA Safeguards?*, Australian Safeguards and Non-Proliferation Office, www.asno.dfat.gov.au/publications/weaponisation_inmm072006.pdf.

²⁴⁹ Perkovich, “Nuclear Power in India, Pakistan, and Iran,” 193.

²⁵⁰ Gun-type assemblies using enriched uranium involve a hemisphere, while implosion type devices use fissile material—whether uranium or plutonium—in a spherical shape.

²⁵¹ Carson Mark et al, *Can Terrorists Build Nuclear Weapons?*, Nuclear Control Institute, Washington D.C., <http://www.nci.org/k-m/makeab.htm>.

²⁵² For a more detailed analysis of how oxides can be used in a nuclear weapon see: Michael Levi, *On Nuclear Terrorism*, (Harvard University Press: Cambridge, 2007), 67.

²⁵³ Mark.

material in a peaceful nuclear program, but the machine tools used are highly sophisticated and their export controlled by the Nuclear Suppliers Group.²⁵⁴

Assessing the ability of a state to make the leap from power production to assembling a nuclear device, however, is typically expressed as a matter of “when” rather than “if” it successfully gets there. The time it takes can be long though, even assuming the availability of sufficient resources, funding, personnel and political support. It was thirteen years until North Korea detonated its first device after it was caught violating the NPT in 1993. The gap between power production and device assembly is, nonetheless, not marginal and can be prohibitively difficult in some cases, particularly if the state is already under intense international scrutiny and receiving no outside help.

A uranium versus plutonium device

Building a uranium device is considerably easier than its plutonium counterpart. Uranium weapons are typically gun-type assemblies in which a smaller piece of uranium is shot into a larger semi-sphere of uranium so that it reaches critical mass and explodes. The basic principles for a gun-type uranium device are widely available in the open literature.²⁵⁵ A plutonium device is an implosion device in which explosives are carefully placed around the outside of a sphere of plutonium, causing the plutonium to increase in density upon detonation, thereby creating a critical mass. Plutonium devices require this more complex design because of the spontaneous fission problem of certain isotopes of plutonium. Implosion weapons are a significant technical challenge for states without access to nuclear weapon experts despite explosive lenses and other shaped explosives

²⁵⁴ Boyd and Cole, “The technological component of collective security,” *Inter American Defense College Library*, 1994.

²⁵⁵ “Technical Background: Nuclear Weapons Design and Materials,” *Nuclear Threat Initiative*, http://www.nti.org/e_research/cnwm/overview/technical2.asp (accessed 7 January 2009).

being more widely used in conventional weapons and commercial applications.²⁵⁶ They are hard to engineer because of the precision required for detonation.

While building a bomb using plutonium is certainly within the reach of some states, it is not simple. Even states that have built dedicated production reactors to acquire plutonium have failed, most notably Pakistan. This may have been the case in North Korea's October 2006 nuclear test, though there is some debate over whether the test was a failed test or a bomb of very low yield.²⁵⁷ In any case North Korea's May 2009 test was a successful test of a nuclear device. Many states have nonetheless decided that the difficulties in building a nuclear device using plutonium are outweighed by the relative ease of acquiring the material.

Assessment

Determining how difficult it is for a state that possesses the necessary material to go on to build either a uranium or plutonium nuclear device is a matter of degree. There are steps involved in both that are complicated and require expertise in areas that are otherwise unrelated to peaceful nuclear energy—not the least of which are the political, organizational and financial factors that have to be conducive to a new military program.²⁵⁸ This expertise and other pre-requisites are, however, obtainable for a determined state. Most proliferation experts agree—probably correctly—that most states with an industrial infrastructure have the potential to make at least a crude nuclear

²⁵⁶ “Technical Background...” *Nuclear Threat Initiative*.

²⁵⁷ For a more detailed analysis of North Korea's 2006 nuclear test see: Thomas C Reed and Danny B Stillman, *The Nuclear Express: A Political History of the Bomb and Its Proliferation*, (Zenith Press: Minneapolis, 2009).

²⁵⁸ Peter Pringle and James Spigelman, *The Nuclear Barons*, (Avon Books: New York, 1981).

explosive if they acquire the material.²⁵⁹ To illustrate the point two American physicists with no nuclear weapons expertise were able to successfully design a nuclear implosion device using only open source literature in the 1960s as a part of the Pentagon's "Nth Country Project".²⁶⁰ So while designing and building a nuclear device is no easy task and can involve significant delays, a determined state is likely capable of doing so with little outside assistance. The nonproliferation regime has as a result—among other reasons—identified restricting the availability of weapons grade fissile material as the focus for its efforts to prevent states from going nuclear and not on device design and assembly.

Overview

There is no systematic way to account for all of the connections between a peaceful nuclear program and a nuclear weapons program. Although establishing the technical connections between the two in terms of scientific knowledge is feasible, there are a number of unquantifiable benefits a state can derive from a peaceful program related to expertise, personnel, infrastructure and camouflage of a clandestine military program. These benefits are difficult to measure but they are also the most important to appreciate.

The scientific knowledge a state can gain from a once-through nuclear program is only the beginning of what a state would need to learn to be able to build a nuclear device. It provides a basic foundation in nuclear science and reactor engineering that is necessary for a state's scientists to understand, but not nearly sufficient. Additional scientific knowledge would need to be obtained about enrichment and/or reprocessing as

²⁵⁹ The Nuclear Threat Initiative reinforces this claim in its technical background of nuclear weapons: http://www.nti.org/e_research/cnwm/overview/technical2.asp.

²⁶⁰ For a more detailed and entertaining account of the Nth Country Project see: Oliver Burkeman, "How two students built an A-bomb," *The Guardian*, 24 June 2003, <http://www.guardian.co.uk/world/2003/jun/24/usa.science>, (accessed 31 March 2009).

well as bomb design and construction. The divisions used in this chapter—the once-through fuel cycle, sensitive fuel cycle technology and nuclear device design and assembly—represent roughly equal steps, in terms of complexity, towards having the full scientific understanding needed to design and build a nuclear device:

Scientific knowledge spectrum

No nuclear capability	Once-through nuclear program	Sensitive fuel cycle technology	Device design and assembly	Full nuclear weapons capability

The catch is that this scientific knowledge is of secondary importance to the expertise, personnel, infrastructure and camouflage that a peaceful program provides. Having these enables a state to obtain much of the additional scientific knowledge required for a nuclear device using open source literature and, if time is not a major issue, some trial and error.²⁶¹ Using the same three divisions, the proportions on the broadly defined infrastructure side look much different:

Expertise, personnel, infrastructure and camouflage spectrum

No nuclear capability	Once-through nuclear program		Sensitive fuel cycle technology	Device design and assembly	Full nuclear weapons capability

A once-through nuclear program has much more to offer on this side of the equation.

Given the robustness of the nuclear export and safeguards regimes now in existence a state seeking nuclear weapons would benefit greatly by pursuing a peaceful energy

²⁶¹ Contrary to popular belief, detailed weapons designs are not readily available in the open source literature: Private e-mail exchange with Atomic Energy of Canada Limited (AECL) employee, September 2008. States have, however, managed to base simpler weapon designs on open source information, such as South Africa's use of American open source information to design its uranium weapon. See "South Africa Profile – Nuclear," Nuclear Threat Initiative, http://www.nti.org/e_research/profiles/SAfrica/Nuclear/index.html (accessed 19 March 2009).

program first for the purpose of building up the necessary infrastructure that it provides. Having to obtain a peaceful nuclear power capacity first does, however, create an additional barrier to the determined state to the extent that safeguards act as a deterrent to diverting a peaceful program to weapons purposes. A decision to illicitly develop nuclear weapons must inevitably take into consideration that its known peaceful facilities are being closely monitored by the IAEA, and diverting resources would be difficult to conceal. These charts are, of course, an oversimplification, but they help visualize the link between peaceful nuclear technology and the acquisition of a nuclear device.

With a once-through program scientists are being given the basic tools with which they can later pursue other nuclear-related technologies including enrichment, reprocessing and device design and assembly. It takes time, resources and especially determination for a state to disregard its international legal obligations and illicitly pursue a technology it has committed itself to never pursue, but in terms of sheer capability if a state can successfully operate its own nuclear reactors it has the potential to pursue nuclear weapons. The technical connection between peaceful nuclear energy and nuclear weapons is important, but it is only one consideration. The motivation of states to acquire nuclear weapons is the more important concern.

Assessing capability is not the same as assessing the motivation of states or the likelihood of new nuclear-armed states emerging. To equate capability with the inevitability of proliferation would be little more than a throwback to the long-dismissed theories of technological determinism discussed previously. Predictions in the 1960s that dozens of new nuclear-armed states would emerge were incorrect and, barring a drastic change in the global order, predictions that several will emerge in the coming decades simply because they have the technical capacity to do so are likely as inaccurate.

Chapter 4 – Global survey of proliferation risk

The historical record and appreciation for the interdependencies within the international system show that the majority of states are not likely to risk the stigma and isolation that would follow in the revelation of an illicit nuclear weapons program. The proliferation theories discussed in chapter two are indeed intended to explain why most states forgo the bomb while a few do not. In assessing the proliferation risk of the purported nuclear revival it is therefore more useful to identify those states that appear to be particularly predisposed towards potential nuclear proliferation rather than analyze in depth the motivations of states that are clearly not likely candidates. This chapter uses a series of indicators to identify potentially high risk states in the context of the purported nuclear revival in two steps.

The first step is to identify those aspiring nuclear energy states that have the capacity to succeed in acquiring nuclear energy. A nuclear energy program is not a necessary step towards developing nuclear weapons. Other pathways to the bomb exist, but answering the question of whether states are pursuing nuclear power for a realized or latent weapons capability is dependent on those states succeeding in acquiring it. Some of the states in question simply do not have the prerequisites—notably financial resources and physical infrastructure—to move forward with their nuclear energy ambitions in the coming years, and in some cases decades. Inability to acquire nuclear energy does not necessarily preclude a state from being motivated by nuclear weapons, but it does diminish the gravity and the seriousness of that motivation. As Mitchell Reiss explains in *Without the Bomb: The Politics of Nuclear Nonproliferation*:

*Nuclear proliferation is a function of two variables: technological capability and political motivation. Both must be present for a country to acquire nuclear weapons. The capability without the motivation is innocuous. The motivation without the capability is futile.*²⁶²

Given that the overarching objective of this thesis is to assess the weapons proliferation risk of the potential spread of nuclear power technology, states that clearly do not have the potential to implement nuclear power for sheer capacity reasons are not of concern to the particular research question posed here regardless of their motivations. Their intent to pursue nuclear weapons through other means cannot, however, be discounted.

The second step is to review the motivations of those states that do seem to have the potential to succeed. A number of indicators have been drawn from theories of proliferation to assess a state's proliferation risk. Using these measures will help to eliminate states that clearly do not appear to have nuclear weapons aspirations. In doing so this research can focus on those states where both technological capability and nuclear weapons motivations may coincide.

Capacity

There are several barriers that can prevent a state from succeeding in its plans to implement nuclear power, the most notable of which were discussed in chapter one. An accurate assessment of many countries' probability of success requires in depth knowledge of each individual state, and especially how it makes its energy decisions and then finances energy projects. There are, however, some indicators that can rule out countries from being capable of acquiring nuclear power by 2030. These are countries

²⁶² Reiss, 247.

that would need to make unprecedented progress in their economic development in a short period of time before nuclear power is even a feasible option. The unpreparedness of these countries is revealed by three easily measurable indicators: existing installed electrical capacity, gross domestic product and their credit ratings. These three measures are probabilistic, not deterministic. They will rule out states that are unlikely to succeed with their peaceful nuclear energy plans, but do not exclude the possibility that some of those states may ultimately succeed, such as by taking advantage of joint products or financial assistance from other states.

Installed electrical capacity

The clearest indicator that a country does not have the prerequisites to move forward with introduction of a nuclear power plant is its existing electrical grid capacity. Current Generation-III nuclear power plants have increased in size from their Generation-II predecessors, meaning one new nuclear power unit represents a larger portion of a country's electrical grid.²⁶³ Older reactor models, typically smaller than 1,000 MW, are no longer generally available commercially for a host of business reasons, including company mergers, licensing issues and profitability concerns.²⁶⁴ There are five major companies promoting their nuclear reactors abroad:

²⁶³ World Nuclear Association, "Advanced Nuclear Power Reactors", <http://www.world-nuclear.org/info/inf08.html> (accessed 25 July 2009).

²⁶⁴ Trevor Findlay, *Report of Nuclear Energy Futures Project – The future of nuclear energy to 2030* (Waterloo: Centre for International Governance Innovation, (forthcoming 2010)).

Table 2 – Generation-III Reactors

Company	Reactor ²⁶⁵	Minimum Production (MW)
Atomic Energy of Canada Limited ²⁶⁶	ACR-1000	1080
AREVA	EPR	1600
GE Hitachi	ESBWR	1520
Russian Federation	VVER-1200	1150
Westinghouse	AP-1000	1000

Source: World Nuclear Association, “Advanced Nuclear Power Reactors”, <http://www.world-nuclear.org/info/inf08.html> (accessed 25 July 2009).

The nuclear reactors available on the market now are relatively large, with the smallest being a 1,000 MW reactor. One generating unit can only account for a certain percentage of the total generating capacity of an electrical grid in order to ensure the integrity of the grid, and in the particular case of nuclear power plants for safety reasons.²⁶⁷ The IAEA states that one reactor should account for no more than 5 to 10 percent, while the World Nuclear Association claims the number is 15 percent.²⁶⁸ Taking the IAEA’s high estimate of 10 percent as a median, a state would need to have an electrical grid with an existing capacity of 9,000 MW to be able to support a single 1,000 MW nuclear power plant.

²⁶⁵ Full reactor names are as follows: Advanced CANDU Reactor 1000 (ACR-1000), European Pressurized Reactor (EPR), Economic Simplified Boiling Water Reactor (ESBWR), Water-Water Energetic Reactor 1200 (VVER-1200) and Advanced Passive 1000 (AP-1000).

²⁶⁶ Atomic Energy of Canada Limited’s future is currently in question as a result of the Canadian government’s announcement that it is going to privatize the power reactor parts of the company’s activities. As a result it is uncertain if the AECL will emerge as a global competitor. For a detailed account of the uncertainty of nuclear power in Canada see: John Cadham, “The Canadian Nuclear Industry: Status and Prospects”, *Nuclear Energy Futures Paper No. 9*, Centre for International Governance Innovation, (forthcoming).

²⁶⁷ Phillip F. Schewe, *The Grid* (Washington DC: Joseph Henry Press, 2007); IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*, 39.

²⁶⁸ IAEA, *Milestones in the Development of a National Infrastructure for Nuclear Power*, 39; World Nuclear Association, “Advanced Nuclear Power Reactors”.

There is a potential alternative in the form of smaller nuclear power plants, but they have not yet been commercialized. According to the World Nuclear Association there are numerous ongoing projects working toward developing cost effective smaller power reactors ranging from 27 to 300 MW.²⁶⁹ According to the Nuclear Energy Agency, these smaller reactors are not likely to be available commercially until between 2010 and 2030²⁷⁰—a 20-year lead time that does not inspire confidence in their reaching energy markets soon—and will not likely play a role in the purported nuclear revival.²⁷¹ These reactors are furthermore problematic because their cost effectiveness is largely dependent on there being a high demand for them—an outcome that is far from certain.²⁷² The most telling example of the challenges of small reactors is the Pebble Bed Modular Reactor (PBMR), previously being developed by a South Africa-led consortium. The PBMR is the most prominent small reactor project and was once thought to be the future of small nuclear power reactors.²⁷³ After ten years of investment South Africa abandoned its plan to implement a fleet of small nuclear reactors in June 2009, putting into question the future of the reactor.²⁷⁴ Until a small reactor is demonstrably proven to be a viable alternative to larger reactors it cannot be assumed that they are an option for aspiring nuclear states.

The logical conclusion of this overview of current reactor types is that states moving forward with their nuclear energy plans will need to do so on the basis of these larger

²⁶⁹ World Nuclear Association, “Small Nuclear Power Reactors”, <http://www.world-nuclear.org/info/inf33.html> (accessed 25 July 2009).

²⁷⁰ Nuclear Energy Agency, 381-382.

²⁷¹ Stephen Thomas et al., “The economics of nuclear power – Research report 2007,” (Greenpeace, 2007): 19.

²⁷² Thomas et al., 19.

²⁷³ World Nuclear Association, “Small Nuclear power Reactors”.

²⁷⁴ Steve Thomas, “The demise of the pebble bed modular reactor,” *Bulletin of the Atomic Scientists*, 22 June 2009, <http://thebulletin.org/web-edition/features/the-demise-of-the-pebble-bed-modular-reactor> (accessed 25 July 2009).

1,000 MW reactors. States with grid capacities substantially less than 9,000 MW therefore will not have the basic physical infrastructure to support the introduction of a nuclear power plant. Some of these states will increase their installed capacity over the

Table 3 – 2006 Installed Electrical Capacity

State	Installed Capacity (MW)
Turkey	38,843
Saudi Arabia	33,535
Poland	30,851
Thailand	26,272
Indonesia	24,263
Malaysia	23,333
Venezuela	22,135
Egypt	20,467
Kazakhstan	18,734
United Arab Emirates	15,710
Vietnam	11,340
Kuwait	10,855
Belarus	8,025
Syria	7,502
Algeria	6,470
Nigeria	5,960
Libya	5,438
Morocco	5,033
Bangladesh	4,710
Tunisia	3,320
Oman	2,983
Qatar	2,829
Bahrain	2,319
Jordan	2,098
Albania	1,684
Ghana	1,490
Mongolia	832
Senegal	507
Namibia	264

Source: Energy Information Administration, "International Energy Statistics", <http://www.eia.doe.gov/> (accessed 22 July 2009).

²⁷⁵ Only the two previously mentioned examples of the Baltic and Gulf states have involved discussions of sharing the burden of a new plant. See: Nuclear Energy Futures Project.

²⁷⁶ Rounding Nigeria's 5,960 MW generating capacity up to 6,000 MW.

next two decades, so it is important to leave room for growth before discounting them. It is also important to bear in mind that sharing electricity across borders where interconnected grids exist is also a possibility, but one that has not yet factored prominently into most aspiring nuclear states' justifications for pursuing nuclear energy.²⁷⁵ There are currently 17 of the 29 states pursuing nuclear energy that cannot support a 1,000 MW reactor without further investment in their generating capacity. Of these states, 13—those at less than 6,000 MW²⁷⁶—would need to increase their generating capacity by over 50 percent to bring it to the minimum 9,000 MW. These 13 aspiring nuclear states will not be able to move forward with their nuclear plans due to a combination of the large size of currently

available reactors and their relatively small installed electrical capacity.

Financial indicators

The other main indicator that a state may not be able to follow through with its nuclear plans is its ability to afford and finance a nuclear plant. Estimates for the cost of a single 1,000 MW plant can vary considerably, but typically range anywhere from USD 5 to 10 billion.²⁷⁷ A recent example is Atomic Energy of Canada Limited's "all-in" bid for two new 1,200 MW ACR-1000s of CAD 26 billion, which was rejected by the Ontario government for being too expensive.²⁷⁸ For relatively poor countries paying for a nuclear power plant is a massive undertaking, and in most cases beyond what is reasonable for them. The example of Bangladesh's five decade-old nuclear ambition cited earlier is just one instance of the challenges of financing problems grinding nuclear projects to a halt.

There is no exact way to measure whether or not a country can afford to pay for a nuclear power plant. The challenge of measuring financing ability is further complicated by the diversity of public-private economies among the 29 aspiring nuclear states, and varying public resources. Whether nuclear projects are financed by public or private capital in these countries also differs. A country's Gross Domestic Product (GDP) in tandem with its credit rating can, however, provide an indication of whether it seems likely to be able to afford and/or procure financing for a multi-billion dollar long-term project.

States with both a low GDP and a poor credit rating are not likely to be able to fund a USD 5 to 10 billion nuclear power plant project. This is especially true for those states

²⁷⁷ Squassoni, 32.

²⁷⁸ Tyler Hamilton, "\$26B cost killed nuclear bid," *Toronto Star*, 14 July 2009, <http://www.thestar.com/article/665644> (accessed 22 September 2009).

that have no credit rating, indicating that there is little outside interest in investment in those states. States with poor or no credit ratings are more likely to be dependent on their own wealth to fund a nuclear power project due to the challenges they would face attracting foreign direct investment. The following table displays the GDP and credit ratings of the 29 aspiring nuclear states. Those states that are grayed out are those that have already been identified as unlikely to succeed because of their inadequate electrical grids. It is clear from the table that there is a strong correlation between grid capacity and economic strength, which intuitively makes sense. GDP figures are 2007 figures from the Central Intelligence Agency's (CIA) World Factbook, while credit ratings are taken from Standard and Poor's, one of the world's leading financial market intelligence firms.

Table 4 – GDP and Credit Ratings

State	2007 GDP (billion USD)	Credit Rating	State	2007 GDP (billion USD)	Credit Rating
Turkey	893.10	BB-	Belarus	129.70	BB+
Indonesia	863.10	BB-	Syria	104.50	B+
Poland	636.90	A-		90.99	
Saudi Arabia	553.50	AA-		83.59	
Thailand	533.70	BBB+		78.21	BBB
Egypt	414.10	BB+		76.75	AA-
Malaysia	367.80			62.97	A
Venezuela	357.90	BB-		32.02	B+
Nigeria	318.70	BB-		29.07	BB
Algeria	228.60			25.17	A
Vietnam	227.70	BB		20.92	B+
	213.60			20.57	
Kazakhstan	171.70	BBB-		10.87	
United Arab Emirates	171.40	AA		8.70	
Kuwait	137.40	AA-			

There are 9 states in this table that had GDP's of less than USD 100 billion²⁷⁹ in 2007 and that have uncertain (BBB or lower) or non-existent credit ratings. Since nuclear plants are high capital cost, long-term projects these states are not likely to be able to fund them independently due to their low GDPs, and would be unlikely to attract foreign investors due to their poor or non-existent credit ratings. To put these benchmarks in perspective, Pakistan is the poorest nuclear weapon state that also has civil nuclear power reactors, and its GDP in 2008 was USD 427.30 billion, with a credit rating of B-.²⁸⁰ Procuring loans from international lending institutions such as the World Bank or Asian Development Bank is also not an option for these states. These lending institutions do not fund nuclear power plants because costs are too often underestimated, they have high up front capital costs and are too large and inflexible for developing countries.²⁸¹ Of these 9 states, 8 have already been eliminated because of their electrical grids. Syria is the only state with the potential to acquire an adequately sized electrical grid, but lacking the financial resources to acquire nuclear power.

Results

Taking current electrical grid capacity and financing together, a number of states can be taken out of the proliferation equation in the context of the purported nuclear revival. These states do not seem to meet the basic prerequisites for successfully obtaining a peaceful nuclear energy program, and are therefore not a proliferation risk as a direct

²⁷⁹ This is an arbitrary number, but an extremely generous one. Bangladesh (discussed previously) and Egypt (to be discussed later) have both failed to acquire nuclear power for financial reasons, yet they are two of the wealthier states in the research population.

²⁸⁰ North Korea's GDP in 2008 was USD 40 billion, but the country does not generate electricity using nuclear power.

²⁸¹ World Bank Environment Department, World Bank Technical Paper #154: Environmental Assessment Sourcebook Volume III," April 1994: 83-89.

result of an expansion in nuclear energy.²⁸² States with current installed electrical capacities of less than 6,000 MW cannot independently support a new nuclear power plant now or in all likelihood within at least the next two decades.²⁸³ These 13 states are:

- Albania
- Bahrain
- Bangladesh
- Ghana
- Jordan
- Libya
- Mongolia
- Morocco
- Namibia
- Oman
- Qatar
- Senegal
- Tunisia

There is also one state, Syria, that may be able to overcome the electrical grid problem, but is not likely to be able to afford a new nuclear power plant based on its small economy and non-existent credit rating. Taking the electrical grid and economic criteria together, 14 of the 29 aspiring nuclear energy states have low chances of successfully implementing a nuclear power program by 2030:

- Albania
- Bahrain
- Bangladesh
- Ghana
- Jordan
- Libya
- Mongolia
- Morocco
- Namibia
- Oman
- Qatar
- Senegal
- Syria
- Tunisia

Several states in Asia, Africa and the Middle East especially do not seem to be prepared to begin implementing a nuclear energy program. There are ways—particularly through

²⁸² There are an endless number of other possible ways for an expansion in nuclear energy to indirectly contribute to proliferation that are not being addressed here, but cannot be discounted. For example, Abdul Qadeer Khan learnt much of what he needed working on uranium enrichment at UNESCO in the Netherlands, and a nuclear revival increases the potential for these types of scenarios repeating.

²⁸³ As previously discussed this does not rule out the possibility of collaborative projects that are of less proliferation concern.

cooperative projects with other interested states—that nuclear power may be an option by 2030 in some of these states, although it seems highly unlikely. Proliferation risk is nonetheless much less likely to materialize in the form of new latent capabilities in these states as a part of the purported nuclear revival because they probably lack the capacity for an independently run nuclear program.

If the motivations for nuclear energy of one or a few of these states is to acquire a latent nuclear weapons capability then they are not pursuing a pathway to the bomb that they are likely to be successful with. The potential nuclear weapons motivations of states lacking the technological capacity to acquire nuclear energy should not be taken as a reflection of the proliferation risk of new nuclear energy states emerging. Analysis within the context of the purported nuclear revival should instead be devoted to those states that could potentially acquire and misuse a peaceful nuclear infrastructure for weapons purposes.

Motivation

The remaining 15 states have a higher chance of acquiring a nuclear power plant by 2030 and therefore have the capacity to be a proliferation concern, but capacity without motivation is, as Reiss put it, innocuous. This section will use indicators to try to determine where possible weapons motivations might exist in the 15 remaining aspiring nuclear energy states, with the purpose of identifying states that may intend to acquire a latent nuclear weapons capability. Those states, organized by region, are the following:

Table 5 – Potential New Nuclear Energy States

Region	Country			
Central Asia	Kazakhstan			
Africa	Algeria	Nigeria		
Europe	Belarus	Poland		
Middle East	Egypt	Kuwait	Saudi Arabia	Turkey
	UAE			
South America	Venezuela			
Southeast Asia	Indonesia	Malaysia	Thailand	Vietnam

The states in the above table are those states that seem most able to acquire at least one nuclear power plant by 2030. The proliferation risk that these states pose will be assessed based on a combination of their strategic situations with respect to nuclear weapons and their international legal obligations. These indicators are drawn from the realist and liberalist views of why states proliferate respectively.

There are three caveats and assumptions that are important to this section. The first is that, like the previous section, results are merely probabilistic, not deterministic. The outcome does imply that the states identified as being of higher proliferation risk will ultimately pursue nuclear weapons, nor that the states that are not identified will ultimately refrain from doing so. It is simply identifying most likely candidates. Second, the principle of multi-causality discussed in chapter two is applied here. That is, no one theory of proliferation is accepted as being more correct, but instead indicators are used from multiple theories that, taken together, can hopefully paint a picture illustrating which

states appear to be particularly predisposed to nuclear weapon motivations and which do not. And third, because this section examines 15 states, only indicators that are easily measurable are used. Theories emphasizing domestic determinants and sociological or psychological drivers, while important, cannot be applied to this global survey because they require in depth knowledge of each individual state. These theories tend to rely on state specific data that cannot easily be aggregated across 15 states. For example, determining if the leaders of each of the 15 remaining states are “oppositional nationalists”—a term derived from Hymans’s theory—requires a certain level of country expertise in each individual case that cannot rightly be claimed in the context of a global survey in a limited number of pages. These more complex determinants of proliferation will instead be examined (in chapter five) within the context of the states identified as being of higher proliferation risk by the more easily measurable indicators used in this chapter.

Nuclear threat perception

A state’s relationship to nuclear weapon states and its past nuclear weapons aspirations are good indicators of whether underlying security challenges that often precede decisions to pursue nuclear weapons exist for a given state. These indicators are strategic determinants of nuclear weapons decisions that are prominent in realist theories of proliferation. In this section states’ predisposition to nuclear weapons will be measured by the presence of rival regional powers that do possess them, positive security guarantees from a nuclear armed state, and evidence of past nuclear weapons activities. Nuclear hedging is an action undertaken by states to deal with their perceived strategic

challenges, so these indicators are of particular importance to determining if states are pursuing nuclear energy for a latent weapons capability.

Strategic determinants of proliferation are essentially based on threat perception as determined by relative power. A state can perceive a threat “requiring” it to pursue nuclear weapons at either the strategic or regional level. For example, Southeast Asian states have long viewed the Chinese nuclear arsenal as a threat, although not such that it has led them to pursue nuclear weapons. Strategic threats may be important in the cases of Iran and North Korea, but do not feature prominently in analysis of the 15 remaining states. This section will therefore emphasize regional threats, particularly given that the concept of nuclear hedging emphasizes regional rivalries, such as that between Middle Eastern states and Iran or Israel.

A state can view a regional power with nuclear weapons as either a stabilizing or destabilizing force depending on its relationship with that state. If a long history of stability between the nuclear weapon state and non-nuclear weapon state exists a sudden decision to pursue nuclear weapons is not likely unless, perhaps, that stability is somehow jeopardized. Table 6 shows the remaining aspiring nuclear energy states organized by geographic region, but with nuclear armed states—whether allies, possible threats or in between—in each region listed as well²⁸⁴:

²⁸⁴ There are currently 9 nuclear weapon states in total: United States (North America), Russia (Central Asia), China (East Asia), Britain (Europe), France (Europe), India (South Asia), Pakistan (South Asia), Israel (Middle East) and North Korea (East Asia).

Table 6 – Regional Nuclear Armed States

Region	Country			Nuclear Armed States
Central Asia	Kazakhstan			Russia
Africa	Algeria	Nigeria		None
Europe	Belarus	Poland		Britain, France
Middle East	Egypt	Kuwait	Saudi Arabia	Israel
	Turkey	UAE		
South America	Venezuela			None
Southeast Asia	Indonesia	Malaysia	Thailand	None
	Vietnam			

Table 6 warrants further explanation so that it is not misleading. It is not intended to be an oversimplified summary of global nuclear tensions, and these tensions of course exist beyond these arbitrary regional boundaries. Nuclear weapons in a state outside of these regional boundaries can indeed be perceived as threatening by certain remaining aspiring nuclear energy states, much in the same way military alliances that extend beyond these regions can be reassuring. Regional considerations are, however, in the view of scholars such as Etel Solingen, critical in determining why some regions appear particularly predisposed towards attempting to acquire nuclear weapons and why others do not.²⁸⁵ The existence of a regional nuclear-armed rival may not only be an important factor in a state's nuclear weapon decisions, but its existence is also potentially reflective of attitudes

²⁸⁵ Solingen, 3-22.

towards nuclearization in the region writ large.²⁸⁶ For example, Solingen explains why nuclear decisions in Southeast Asia and the Middle East have historically contrasted:

*East Asian leaders pivoted their domestic political control on economic performance and integration into the global economy. Middle East leaders relied on inward-looking self-sufficiency and an emphasis on domestic markets and nationalist views for their political survival. These respective platforms created different incentives and constraints that influenced leaders' preferences for or against nuclear weapons.*²⁸⁷

Regional dynamics are therefore important in assessing the strategic circumstances of the remaining aspiring nuclear energy states, although that is not to say that strategic considerations beyond these arbitrary regions are not potential factors as well.

The existence of a nuclear-armed “regional rival” is an indicator that states in that region may be more likely to pursue nuclear weapons, as Solingen’s argument suggests. A regional rival, for the purposes of this thesis, refers to a state with poor relations with an aspiring nuclear energy state, or many states, in the region that can be perceived as a potential security threat. The only nuclear-armed state in Table 6 that can be considered a regional rival to other states in its region is Israel in the Middle East. Israel’s nuclear weapons have indeed been long considered a major source of tension in the Middle East.²⁸⁸ A September 2009 statement by Egyptian foreign minister Ahmed Aboul Gheit emphasized the significance of nuclear-armed states in the region, stating that the combination of a nuclear armed Israel and potentially Iran “would trigger an arms race [in

²⁸⁶ Solingen, 5.

²⁸⁷ Solingen, 5.

²⁸⁸ See: Robert Harkavy, *Spectre of a Middle Eastern Holocaust: the strategic and diplomatic implications of the Israeli nuclear weapons program* (Denver: University of Denver Press, 1977); Louis René Beres (ed.) *Security or Armageddon: Israel's nuclear strategy* (Lexington: Lexington Books, 1986); James A. Russell, *Proliferation of weapons of mass destruction in the Middle East: directions and policy options in the new century* (New York: Palgrave-Macmillan, 2006).

the Middle East].”²⁸⁹ On the other hand the relationships between Britain, France and Russia and their respective regional aspiring nuclear energy states involve high levels of economic integration and in some cases military alliances. Britain, France and Russia can therefore not credibly be considered regional rivals with respect to the states in their respective regions. The aspiring nuclear energy states in the Middle East are more likely to aspire to nuclear weapons because of the presence of Israeli nuclear weapons, and the potential for an ensuing cascade of proliferation that may begin with Iran.

Table 7 – Positive Nuclear Security Guarantees

State	Positive Nuclear Security Guarantees
Algeria	No
Belarus	No
Egypt	No
Indonesia	No
Kazakhstan	No
Kuwait	No
Malaysia	No
Nigeria	No
Poland	US, Britain, France
Saudi Arabia	No
Thailand	US
Turkey	US, Britain, France
United Arab Emirates	No
Venezuela	No
Vietnam	No

The role of alliances and positive nuclear security guarantees are also critical in assessing states’ predisposition towards pursuing nuclear weapons. A positive security guarantee refers to the commitment on behalf of a nuclear weapon state to defend a non-nuclear weapon state from nuclear threats, often referred to as a “nuclear umbrella” or “extended deterrence”.²⁹⁰ A positive guarantee is in contrast to a negative nuclear security guarantee, which is a

commitment by a nuclear weapon state to a non-nuclear weapon state not to use its

²⁸⁹ “Egypt warns of Mideast nuclear arms race,” *The Associated Press*, 26 September 2009, <http://www.google.com/hostednews/ap/article/ALeqM5gpqwbzgrMHn8Sz-3odOcGceu-N0wD9AUJPQ00> (accessed 27 September 2009).

²⁹⁰ See: Stephen J. Simbala, *Extended deterrence: The United States and NATO Europe* (Lexington: Lexington Books, 1987); Paul K. Huth, *Extended Deterrence and the Prevention of War* (New Haven: Yale University Press, 1988); William T. Tow, *Encountering the Dominant Player: U.S. Extended Deterrence Strategy in the Asia-Pacific* (New York: Columbia University Press, 1991).

nuclear weapons against it. Positive security guarantees are important in assessing the proliferation risk of states because where alliance systems are in place and these guarantees exist, the (perceived) security benefit of pursuing nuclear weapons, many deterrence theorists would argue, is drastically reduced.²⁹¹ Deterrence theory is related to realist theories of proliferation in that they both emphasize the strategic dimensions of nuclear weapons as being the primary drivers being nuclear decisions. Table 11 shows aspiring nuclear states that already have a positive nuclear security guarantee, in this case all from the United States.

Poland and Turkey are part of the NATO alliance and therefore benefit from the US, British and French nuclear arsenals. Much has been written about the role of nuclear weapons in NATO, and about its member states free-riding off US military and strategic strength in particular, but it is beyond the scope of this thesis.²⁹² Extended deterrence is nonetheless a feature of the NATO alliance. The US also has longstanding security guarantees in place with Thailand. Thailand—along with the Philippines and South Korea²⁹³—was a US ally in the Asia-Pacific region during the Cold War, leading to a lasting security relationship between the US and Thailand that continues today.²⁹⁴ The security relationships that Thailand maintains with the United States means that it is

²⁹¹ There is an extensive literature discussing deterrence theory and the importance of extended deterrence. In addition to the sources on extended deterrence cited above, see: Alexander L. George and Richard Smoke, *Deterrence in American Foreign Policy: Theory and Practice* (New York: Columbia University Press, 1974); Robert Powell, *Nuclear Deterrence Theory: The Search for Credibility* (New York, Cambridge University Press, 1990); Ian R. Kenyon and John Simpson, *Deterrence and the New Global Security Environment* (New York: Routledge, 2006).

²⁹² Thomas W. Graham, *American Public Opinion on NATO, Extended Deterrence, and the Use of Nuclear Weapons: Future Fission?* (Cambridge: University Press of America, 1989); Robbin F. Laird and Betsy Jacobs (eds.), *The Future of Deterrence: NATO Nuclear Forces After INF* (Boulder: Westview Press, 1989).

²⁹³ Gerald Segal, *Rethinking the Pacific* (Oxford: Clarendon Press, 1990), 246-250; Robert A. Scalapino, "The US Commitment to Asia," in *The Transformation of Security in the Asia/Pacific Region*, ed. Desmond Ball (London: Frank Cass & Co. Ltd, 1996), 80-81.

²⁹⁴ Scalapino, "The US Commitment...", 79-82.

already protected by a nuclear arsenal much larger and more advanced than what it would be able to produce on its own, so according to realist approaches to proliferation it in all likelihood lacks the motivation to pursue nuclear weapons.

Another indicator of proliferation predisposition is whether a state has past experience with nuclear weapons, be it by possessing them or from conducting research into building them. Belarus and Kazakhstan inherited nuclear weapons in 1991 when the Soviet Union collapsed, but were quick to give them up. Belarus did not hesitate long to relinquish the weapons it had inherited in fear of the strategic consequences of being a nuclear armed state in between a potentially unstable Russia and the rest of Europe.²⁹⁵ Kazakhstan did so in order to ensure good relations with the US and to take advantage of the economic incentives that the US provided.²⁹⁶ The unique circumstances in which Belarus and Kazakhstan inherited nuclear weapons are not sufficient to suggest that they are a greater proliferation risk today because of it. While both states have a history with nuclear weapons as well as some residual expertise and infrastructure, they both relinquished them, acceded to the NPT and as far as is known have not since shown any indication that they are interested in reacquiring the bomb.

Egypt, however, not only engaged in nuclear weapons research in the past, but was also caught in non-compliance with its safeguards commitments with the IAEA. This violation in tandem with past weapons research reflects either a desire by at least some elements of society for nuclear weapons and a willingness to engage in unlawful activity, or a lack of commitment to the NPT. Egypt was engaged in nuclear weapons research up

²⁹⁵ Mitchell Reiss, *Bridled Ambition: Why Countries Constrain their Nuclear Capabilities* (Washington: Wilson Center Press, 1995).

²⁹⁶ Cynthia Werner and Kathleen Purvis-Roberts, "After the Cold War: international politics, domestic policy and the nuclear legacy in Kazakhstan," *Central Asian Survey* 25:4 (2006): 462-466.

until 1970, so there is certainly a history of weapons ambitions in Egypt.²⁹⁷ In 2004, the International Atomic Energy Agency also discovered that Egypt had engaged in undisclosed experiments involving uranium extraction, conversion and reprocessing in the 1980s.²⁹⁸ Egypt also used small amounts of nuclear material to conduct experiments relating to the production of high-enriched uranium and plutonium.²⁹⁹ Egypt has therefore demonstrated an interest in nuclear weapons and a willingness to disregard legal commitments in the past, and can therefore be considered a higher proliferation risk because of it.

International legal commitments

The extent of a state's commitment to nuclear safeguards is one indication of its dedication to nuclear nonproliferation. Nuclear safeguards refer to the measures employed by the IAEA to ensure that peaceful nuclear facilities are not misused for military purposes. A state's commitment to nuclear safeguards are indicative of its integration into the nonproliferation regime and acceptance of the global norm against the acquisition of nuclear weapons. Article III of the NPT requires that all of its member states have a Comprehensive Safeguards Agreement (CSA)³⁰⁰ with the International Atomic Energy Agency:

Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded

²⁹⁷ The International Institute for Strategic Studies (IISS), *Nuclear Programmes in the Middle East: In the shadow of Iran*, (London: The International Institute for Strategic Studies, 2008): 17-20.

²⁹⁸ United States Government Accountability Office, "Nuclear Nonproliferation: IAEA Has Strengthened Its Safeguards and Nuclear Security Programs, but Weaknesses Need to Be Addressed," *Report to Congressional Requesters* (Washington DC: United States Government Accountability Office, 2005): 20.

²⁹⁹ United States Government Accountability Office, "Nuclear Nonproliferation: IAEA...", 20.

³⁰⁰ International Atomic Energy Agency, "The Structure and Content of Agreements Between The Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons," *INFCIRC/153 (Corrected)*, <http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc153.pdf> (accessed 31 July 2009).

*with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices.*³⁰¹

These CSAs require the state to report on all of its nuclear activities and quantities of nuclear material and give the IAEA authority to verify those reports through accountancy and control measures, as well as inspections of nuclear facilities.³⁰² The Nuclear Suppliers Group (NSG) requires a CSA as the minimum legal obligation a state needs to undertake to be eligible for any transfers of nuclear technology. It establishes this requirement through its own internal guidelines, and through IAEA INFCIRC/254 which states:

*Suppliers should transfer trigger list items or related technology to a non-nuclear weapon State only when the receiving State has brought into force an agreement with the IAEA requiring the application of safeguards on all source and special fissionable material in its current and future peaceful activities.*³⁰³

All of the aspiring nuclear energy states therefore have a CSA in effect.³⁰⁴ A CSA, while a legal requirement for parties to the NPT, is a precondition for receiving transfers of nuclear technology, but not necessarily a strong indication of a state's commitment to nonproliferation.

³⁰¹ *Treaty on the Non-Proliferation of Nuclear Weapons (NPT)*, Department for Disarmament Affairs, United Nations, <http://www.un.org/events/npt2005/npttreaty.html> (accessed 31 July 2009).

³⁰² International Atomic Energy Agency, *The Safeguards System of the International Atomic Energy Agency*, http://www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf (accessed 31 July 2009): 2.

³⁰³ International Atomic Energy Agency, "Communications Received From Certain Member States Regarding Guidelines for the Export of Certain Nuclear Materials, Equipment and Technology," *INFCIRC/254/Rev.9/Part 1*, <http://www.nuclearsuppliersgroup.org/Leng/PDF/infcirc254r9p1-071107.pdf> (accessed 31 July 2009).

³⁰⁴ International Atomic Energy Agency, *NPT Comprehensive Safeguards Agreements: Status*, http://www.iaea.org/Publications/Factsheets/English/nptstatus_overview.html (accessed 31 July 2009).

Table 8 – Status of Safeguards Agreements

State	CSA	AP	SQP
Algeria	Yes	No	No
Belarus	Yes	No	No
Egypt	Yes	No	No
Indonesia	Yes	Yes	No
Kazakhstan	Yes	Yes	No
Kuwait	Yes	Yes	Yes
Malaysia	Yes	No	No
Nigeria	Yes	Yes	No
Poland	Yes	Yes	No
Saudi Arabia	Yes	No	Yes
Thailand	Yes	No	No
Turkey	Yes	Yes	No
United Arab Emirates	Yes	No	Yes
Venezuela	Yes	No	No
Vietnam	Yes	No	No

Source: International Atomic Energy Agency, *Safeguards Current Status*, http://www.iaea.org/OurWork/SV/Safeguards/sir_table.pdf (accessed 31 July 2009).

The recognition that the measures outlined in the model CSA were not sufficient for verification of compliance with NPT states parties' obligations became clear after the discovery of a clandestine nuclear weapons program in Iraq after the First Gulf War in 1990-91. In an effort to strengthen verification after the discovery in Iraq, the IAEA took two main steps: first, it expanded the interpretation of authorities already held by the IAEA under existing CSAs

to enhance its verification methods, such as environmental sampling; and second,

it approved a model Additional Protocol (AP)³⁰⁵ to CSAs that, among other provisions, permitted the IAEA access to any facilities in order to verify the absence of nuclear material.³⁰⁶ This AP is the gold standard for a state's legal commitment to nuclear nonproliferation since its implementation began in 1997. Having an AP in force is perhaps one of the clearest indicators that a state does not intend to secretly attempt to develop nuclear weapons because it gives the IAEA intrusive access to its nuclear activities and requires cradle to grave transparency. The AP makes nuclear hedging more

³⁰⁵ International Atomic Energy Agency, "Model Protocol Additional to the Agreement(s) Between States and the International Atomic Energy Agency for the Application of Safeguards," *INFCIRC/540 (Corrected)*, <http://www.iaea.org/Publications/Documents/Infircs/1997/infirc540c.pdf> (accessed 31 July 2009).

³⁰⁶ International Atomic Energy Agency, *The Safeguards System of the International Atomic Energy Agency*, 2.

difficult because it limits the types of experiments and activities a state can undertake that are necessary to divert its peaceful knowledge and infrastructure to weapons applications.

Another indicator of an aspiring nuclear energy state's legal commitment to nuclear nonproliferation is whether or not it has a small quantities protocol (SQP) in effect. A SQP allows a state to possess up to 10 tons of natural uranium, 20 tons of depleted uranium and 2.2 pounds of plutonium without subjecting such materials to safeguards.³⁰⁷ These protocols were designed to allow states with small amounts of nuclear material to forego the most rigorous aspects of verification because they are less than would be necessary for a single nuclear device.³⁰⁸ There are legitimate reasons for states to want a SQP, but a SQP could also be a sign that a state is attempting to avoid safeguards on its nuclear activities. Having a SQP and pursuit of nuclear energy is a potentially problematic combination that heightens the proliferation risk of a particular state. In September 2005, in recognition that in some cases a SQP could be a nonproliferation issue, the IAEA Board of Governors decided that states with a planned or existing nuclear facility are no longer eligible for a SQP.³⁰⁹ Any state pursuing nuclear power should therefore not have one of these protocols in force. If a state with a SQP is serious about both a peaceful nuclear energy program and nuclear nonproliferation, rescinding it is a logical and necessary first step.

Many states may just be slow to adopt Additional Protocols or rescind their Small Quantities Protocols, but both steps are viewed as necessary preconditions for the transfer

³⁰⁷ Alex Pojedinec, "Saudi Nuclear Intentions and the IAEA Small Quantities Protocol," *Center for Defense Information*, 30 June 2005, http://www.cdi.org/program/document.cfm?documentid=3050&programID=32&from_page=../friendlyversion/printversion.cfm (accessed 12 August 2009).

³⁰⁸ International Atomic Energy Agency, "The Structure and Content of Agreements..."

³⁰⁹ International Atomic Energy Agency, *The Safeguards System of the International Atomic Energy Agency*, 3.

of nuclear technology in order to ensure aspiring nuclear states' commitment to nonproliferation.³¹⁰ Table 7 shows the current safeguards status of the 18 remaining states. The number of states in this list that do not have additional protocols in force is alarming considering their interest in nuclear power. As of 9 July 2009, there are 11 countries located in Africa, Europe, the Middle East, South America and Southeast Asia with the potential to acquire nuclear energy but without having adopted the strictest nonproliferation measures. One possible justification for states' refusal to adopt an Additional Protocol is the argument that it is yet another obligation that the nuclear weapon states (NWS) are trying to impose on them for their "inalienable right" to nuclear technology—a right reaffirmed by Article IV of the NPT.³¹¹ For example, Egypt has refused to sign an Additional Protocol because it is voluntary, and does not feel it needs to accept further verification commitments than it already has—an explanation often justified by pointing out Israel's absence from the NPT.³¹² Egypt does not feel it needs to take on additional commitments when a state like Israel is allowed to keep its nuclear arsenal. Whether the inalienable right argument is considered a legitimate grievance or rhetoric is not important in this context. Whatever the argument made by an aspiring nuclear energy state to refuse an AP suggests at best only a limited commitment to nonproliferation. There are also three remaining aspiring nuclear energy states—all in the Middle East—with a Small Quantities Protocol in effect, suggesting that they are not taking the necessary nonproliferation steps to prepare for a nuclear energy program.

³¹⁰ Private conversation with US Department of State official, US Department of State, (Washington, DC: April 2009).

³¹¹ *Treaty on the Non-Proliferation of Nuclear Weapons (NPT)*.

³¹² "Egypt won't sign UN nuclear watchdog protocols," *The Jerusalem Post*, 12 December 2007, <http://www.jpost.com/servlet/Satellite?pagename=JPost%2FJPArticle%2FShowFull&cid=1196847320731> (accessed 27 September 2009).

Any of the 11 states without an Additional Protocol are worth analyzing in more detail if other indicators suggest they are a proliferation risk as well. Two states that appear to be particularly risky on the basis of their safeguards criteria alone are Saudi Arabia and, oddly enough given its proclaimed commitment to nonproliferation, the United Arab Emirates. Neither state has an Additional Protocol in force as of yet³¹³, and they both have a Small Quantities Protocol still in effect, so they both warrant in depth study as a result.

Results

States intending to acquire nuclear energy for a latent weapons capability are best determined by looking for potentially volatile combinations of indicators that give the impression that a state could be motivated by a desire for a weapons option. Problematic combinations of indicators that a state is potentially high risk based on the analysis above are:

- Past covert research into nuclear weapon design, weaponization or uranium enrichment and/or reprocessing (Egypt)
- No Additional Protocol in force, nuclear-armed regional rival and no positive nuclear security guarantee³¹⁴ (Egypt, Saudi Arabia and UAE)
- No Additional Protocol in force, but a Small Quantities Protocol (Saudi Arabia and UAE).

Most of the remaining 18 aspiring nuclear states do not meet these criteria because they either: have an Additional Protocol in force that demonstrates their commitment to nonproliferation and IAEA verification; fall under the US nuclear security umbrella and receive the perceived benefits of nuclear weapons anyway; or have not covertly

³¹³ The United Arab Emirates did sign an Additional Protocol on 8 April 2009, but it has not yet entered into force. Although the UAE is likely to ratify its AP, Iran's signing and subsequent refusal to ratify its AP is a lesson that nothing should be taken for granted. Signature alone is not sufficient.

³¹⁴ Excluding Belarus and Kazakhstan because they have already demonstrated their commitment to nonproliferation by relinquishing their inherited nuclear weapons.

conducted nuclear weapons related experiments. Only three states—Egypt, Saudi Arabia and the United Arab Emirates—meet one or more of the above criteria and will therefore be examined in more detail in the next chapter.

Chapter 5 – Potentially high risk states

The Middle East has long been a source of alarm for the nuclear nonproliferation regime because of its history of attempted nuclear proliferation.³¹⁵ It is not entirely surprising that the three states identified—Egypt, Saudi Arabia and the UAE—are all located in the Middle East. Israel is so far the only state known to have successfully developed and maintained a nuclear arsenal in the region. Israel has maintained a policy of nuclear ambiguity over the years, neither confirming nor denying its nuclear capability, all while remaining mostly outside of the nonproliferation regime.³¹⁶ Israeli nuclear weapons are a major source of tension in the Middle East and analysis of the nuclear weapons ambitions of other states in the region is often framed in terms of how those ambitions relate to Israel. Iran has, however, more recently taken centre stage with its uranium enrichment program and the antagonistic attitude of Mahmoud Ahmadinejad, particularly towards Israel and the United States, though its nuclear weapons ambitions are still unclear.³¹⁷ Israel and Iran therefore feature prominently in the analysis of possible nuclear weapons motivations in any Middle Eastern state. Middle Eastern states have not responded to threats from Israel and Iran in the same way, however, and each warrants individual analysis to determine a possible connection between its nuclear energy aspirations and nuclear weapons.

³¹⁵ Israel has a nuclear arsenal. Iraq's Osirak nuclear reactor was destroyed by Israel in 1981 because it was believed to be intended for military purposes, WMD were discovered in Iraq during the First Gulf War, and the 2003 US invasion of Iraq was predicated on an assumption of ongoing clandestine WMD activity. Libya was caught red-handed importing nuclear equipment and designs through the AQ Khan network and renounced nuclear weapons in 2003. Iran had a dedicated nuclear weapons research program that may have lasted until as recent as 2003 according to some estimates. The alleged Syrian Al-Kibar reactor destroyed in 2007 was suspected of being a plutonium production reactor designed with North Korean assistance.

³¹⁶ See: Beres.

³¹⁷ Emile El-Hokayem and Matteo Legrenzi, "The Arab Gulf States in the Shadow Of the Iranian Nuclear Challenge (Working Paper)," *The Henry L. Stimson Center* (2006).

Egypt

Egypt is one of the more challenging states to assess. Despite having what appear to be legitimate motivations for nuclear energy as well as the technical capacity to implement it successfully³¹⁸, Egypt's nuclear weapons history and inconsistent nonproliferation disposition raise some concern. Egypt was caught in minor non-compliance with its Comprehensive Safeguards Agreement, refuses to sign an Additional Protocol and has not ratified the Comprehensive Test Ban Treaty (CTBT). One study of the nuclear weapons in the Middle East even labelled Egypt as the "usual suspect" because of its long and complicated nuclear history.³¹⁹ Egypt nonetheless remains one of the more outspoken voices in favour of a nuclear weapon-free zone in the Middle East.

Justification for nuclear energy

Current Egyptian President Mohamed Mubarak took power in 1981 and continued his predecessor's plans for acquiring nuclear power plants to supply electricity and for water desalination.³²⁰ Egypt's plans for a large nuclear power reactor were put on hold, along with plans in most of the rest of the world, after the Chernobyl disaster in 1986.³²¹ Egypt has since reinvigorated its efforts with Mubarak's announcement in October 2007 that the country would once again try for a nuclear reactor to meet its energy needs.³²² According to Minister of Electricity and Energy Hassan Younis, Egypt has since taken several steps

³¹⁸ Lindsay Windsor and Carol Kessler, *Technical and Political Assessment of Peaceful Nuclear Power Program Prospects in North Africa and the Middle East*, (Richland: Pacific Northwest National Laboratory, 2007): 9-12.

³¹⁹ IISS: 17.

³²⁰ Windsor and Kessler, 13.

³²¹ Windsor and Kessler, 13.

³²² "Egypt plans to build nuclear power plants," *Daily Commercial News*, 31 October 2007, <http://www.dailycommercialnews.com/article/id24900> (accessed 28 September 2009).

to provide an appropriate infrastructure for a possible 1,000 MW nuclear plant, including preparing a site at Dabba on the Mediterranean coast and putting out a call for bids for the construction of the plant.³²³ Once a bid is accepted, according to Younis, the project will take 10 years to complete costing between USD \$1.5 and \$1.8 billion.³²⁴ So far no bid has been selected, no doubt in large part because Egypt's price range is orders of magnitude lower than the \$5 to \$6 billion it typically costs to build a 1,000 MW nuclear plant. Financial challenges indeed still loom large over Egyptian prospects for a nuclear power plant and despite the country's improved credit rating, the possibility of attracting foreign investors to a major nuclear power project in Egypt—according to the International Institute for Strategic Studies (IISS)—remains extremely remote.³²⁵

Egypt's push for nuclear power, despite the challenges it faces, seems largely motivated by rising energy demand. Electricity demand in Egypt has increased nearly 10 percent per year in the past decade putting strain on Egypt's oil and gas reserves.³²⁶ President Mubarak has stated that, "We have to face the fact that oil and gas in the end are non-renewable energy sources...And we also have to admit that we are facing a great challenge to meet increasing consumption."³²⁷ Since 81 percent of Egypt's energy production comes from fossil fuels—with the remaining 19 percent coming from the Aswan Dam—Egypt is faced with the prospect of declining oil and gas reserves, so Mubarak's justification seems valid.³²⁸ In February 2007, Oil Minister Sameh Fahmy projected that gas reserves would last for another 34 years and crude oil for 13 years.³²⁹

³²³ "Egypt to assess first nuclear plant tender papers," *Egypt News*, 5 May 2008.

³²⁴ "Egypt to Accept Nuclear Construction Bids," *Global Security Newswire*, 28 January 2008.

³²⁵ IISS, 28.

³²⁶ "Egypt's nuclear push," *The Economist*, 2 November 2007.

³²⁷ "Mubarak says Egypt to build nuclear power stations," *Africa Reuters*, 29 October 2007.

³²⁸ Windsor and Kessler, 18.5

³²⁹ IISS, 29.

Egypt does have a legitimate energy security challenge in the coming years, so diversifying its energy portfolio sooner rather than later is prudent planning. With most of Egypt's domestic fossil fuel supply drying up before 2050, Egypt's nuclear energy ambitions are justifiable from an energy security perspective.

Despite the tension between Egypt, Iran and Israel it seems unlikely that Egypt's primary justification for pursuing nuclear power is as a way to hedge against a nuclear-armed Iran, but it is within the realm of reason. Egyptians have long viewed Egypt as a natural leader in the Middle East, dating back to Nasser's presidency when he positioned Egypt as one of the primary players in the Non-Aligned Movement (NAM), supporting neither the United States nor Soviet Union during the Cold War.³³⁰ A nuclear-armed Iran is a potential threat to Egypt's regional status due to the two nations being regional rivals for leadership in the Middle East. Egypt, however, has a long history of often-violent conflict with Israel, dating at least as far back as the first Arab-Israeli War of 1948.³³¹ The seeds of Egypt's conflict with Israel, as with many Arab states in the Middle East, stem from the partitioning of Palestine and the formation of Israel in the aftermath of the Second World War, widely considered a historical injustice in the Arab world.³³² The 1967 Six Day War, fought between Israel and a coalition of Arab states that included Egypt, Jordan and Syria, resulted in the defeat of the Arab states.³³³ The subsequent Yom Kippur War (October War) of 1973 saw the Arab states led by Egypt earn some victories, such as pressuring the US to change its tact regarding the Arab-Israeli conflict, but neither

³³⁰ Arthur Goldschmidt Jr., *Modern Egypt: The Formation of a Nation-State* (Boulder: Westview Press, 1988), 165-166.

³³¹ Goldschmidt, 77.

³³² Yoram Meital, *Egypt's Struggle for Peace: Continuity and Change, 1967-1977* (Gainesville: University Press of Florida, 1997): 1.

³³³ Meital, 12-13.

side had an irrefutable claim to victory.³³⁴ The Egyptians and Israelis eventually reached a formal peace agreement in 1979, marking the end of decades of violent conflict between the two nations.³³⁵

According to IISS, many Egyptians may not feel that a nuclear-armed Iran is a threat to Egypt, and may even shift the balance of power in the Middle East in Egypt's favour because Iran would act as a counter-balance to Israel.³³⁶ For Egypt to react to an Iranian nuclear weapons program seems counter-intuitive given that Egypt refrained from doing so despite decades of violent clashes with nuclear-armed Israel. As one expert puts it, the argument that Egypt might go nuclear in response to Iran "would have to explain why balance of power compels such action vis-à-vis Iran but has hardly operated vis-à-vis Israel, which Egypt has tolerated as a nuclear weapon state for decades."³³⁷ Egypt hedging against a possible nuclear-armed Iran with its otherwise peaceful nuclear program is not a possibility that can be ruled out, particularly given statements such as that of foreign minister Ahmed Aboul Gheit that nuclear weapons in Iran would lead to an arms race in the Middle East.³³⁸ It does, however, seem unlikely given Egypt's legitimate energy security justifications for nuclear energy as well as its history of relative restraint—at least in terms of nuclear weapons—in response to Israeli nuclear weapons despite some modest research efforts and rhetoric stating otherwise. Egypt and Iran may be regional rivals, but this fact alone is not enough to substantiate claims that Egypt would follow Iran if it were to acquire nuclear weapons, particularly with the whole world watching Iran.

³³⁴ Meitel, 126-127.

³³⁵ Meitel, 176-177.

³³⁶ IISS, 30.

³³⁷ Solingen, 244.

³³⁸ "Egypt warns of Mideast nuclear arms race."

Nuclear weapons history and prospects

Part of the challenge with assessing Egypt is that it has been slowly but surely becoming less of a likely proliferation candidate since the 1970s due to internal policy shifts and a cooling of tensions with Israel, so determining current motivations for nuclear weapons is partially dependent on how much weight is placed on past activities. Under Gamal Nasser in the 1950s and 1960s—the country’s first president—Egypt developed a nuclear infrastructure that included the establishment of the Egyptian Atomic Energy Commission (AEC) in 1955—now the Atomic Energy Authority (AEA)—and a 2 MW research reactor that came online in 1961.³³⁹ Most experts agree that Egypt most intensely pursued nuclear weapons under Nasser based on statements and incidents in the 1960s, such as Nasser’s proclamation that if Israel obtained nuclear weapons, “we will secure atomic weapons at any costs.”³⁴⁰ This is as clear an indication of intention to pursue nuclear weapons as can be, but it did not translate well into reality. Tensions between Egypt and Israel reached their peak during the 1967 Six Day War, which had serious implications for Egypt’s peaceful and military nuclear ambitions. Egypt’s loss in the war and its rapidly inflating military expenses resulted in a major economic contraction and deepened the country’s balance of payments crisis to the point where Nasser admitted the country could not fund its nuclear projects.³⁴¹

When Anwar al-Sadat succeeded Nasser as president in 1970, Egypt’s nuclear weapons program was abandoned entirely.³⁴² Egypt eventually ratified the NPT in 1981—13 years after the treaty was opened for signature with Egypt among the first to

³³⁹ “Egypt Profile – Nuclear,” Nuclear Threat Initiative, http://www.nti.org/e_research/profiles/Egypt/Nuclear/index.html (accessed 8 August 2009).

³⁴⁰ “Egypt Profile – Nuclear”.

³⁴¹ Solingen, 240.

³⁴² IISS, 20-23.

sign—putting aside its distaste for Israel’s arsenal and the NPT’s two-tiered system of nuclear “haves” and “have-nots”.³⁴³ Egypt has, for the most part, been in good standing with the nonproliferation regime since its ratification of the NPT in 1981. The notable exception to this is the IAEA’s discovery in 2004 that Egypt had undeclared material and research activities. Small amounts of uranium tetrafluoride, uranium metal and thorium compounds were discovered, as well as plans for plutonium and uranium separation experiments and several other minor safeguards violations.³⁴⁴ Egyptian officials explained the violations as a misunderstanding, claiming that their interpretation of what was required under Egypt’s CSA differed from that of the IAEA and cooperated fully with the IAEA’s investigation, earning US praise in doing so.³⁴⁵ IAEA Director-General Mohamed ElBaradei—an Egyptian himself—concluded in his report on the investigation that:

*The repeated failures by Egypt to report nuclear material and facilities to the Agency in a timely manner are a matter of concern. Egypt has explained that its past failure to report was attributable to a lack of clarity about its obligations under its Safeguards Agreement, particularly as regards small quantities of nuclear material used in research and development activities. Egypt has indicated that it will report any such material and activities in the future.*³⁴⁶

Egypt’s CSA violations are therefore not serious instances of noncompliance, but an apparently legitimate misunderstanding, or at worst a reflection of Egyptian malcontent with having verification measures imposed on its peaceful research. As one study puts it, “Egypt’s infractions were not indicative of a systematic intent to create a latent weapons

³⁴³ Solingen, 263-239.

³⁴⁴ IISS, 24.

³⁴⁵ IISS, 24.

³⁴⁶ Report by the Director General, *Implementation of Safeguards Agreement in the Arab Republic of Egypt*. International Atomic Energy Agency (Gov/2005/9), http://www.globalsecurity.org/wmd/library/report/2005/egypt_iaea_gov-2005-9_14feb2005.pdf (accessed 8 August 2009): 6.

capability.”³⁴⁷ Despite the infraction there does not seem to be any evidence that Egypt has had interest in developing nuclear weapons since it ratified the NPT in 1981.

Nonproliferation disposition

Although there is little evidence to suggest Egypt is currently interested in obtaining nuclear weapons, it does have a poor record regarding making commitments to nonproliferation. Most notably Egypt refuses to sign an Additional Protocol to its CSA. Egyptian Foreign Minister Ahmed Aboul Gheit justified Egypt’s abstention arguing that, “It’s necessary to adhere to the principle of not linking the provision of nuclear energy with the acceptance of obligations not specified in treaties and agreements. Egypt will not accept any additional obligations in this matter.”³⁴⁸ Gheit’s argument is grounded in the reality that the verification burden placed on non-nuclear weapon states has increased, while nuclear weapon states have not met their disarmament commitments and three states have remained outside of the NPT. His argument is further supported by the fact that the NPT does promise peaceful nuclear assistance to states in return for them foregoing nuclear weapons. Egypt’s justification for not signing an Additional Protocol is reflective of its frequent criticism of the nonproliferation regime writ large for being discriminatory. The risk is that the Egyptian government is merely using these faults in the regime as an excuse for avoiding strict verification measures that may detect a potential clandestine weapons initiative. That argument, however, seems unlikely in the Egyptian case as the analysis of Egypt’s nuclear weapon history above suggests.

Egypt has signed but not yet ratified the Treaty of Pelindaba—a treaty that would establish a nuclear-weapon free zone in Africa—despite its major role in pushing for and

³⁴⁷ IIS, 24.

³⁴⁸ “Egypt Refuses to Sign Nonproliferation Protocol,” *Global Security Newswire*, 12 December 2007.

negotiating the treaty.³⁴⁹ Egypt has likely delayed ratification of the treaty because of its more pressing concern of establishing a nuclear weapon-free zone in the Middle East, which would also commit Israel to give up its weapons.³⁵⁰ Egypt has likewise signed but not ratified the Comprehensive Nuclear Test Ban Treaty (CTBT), and Egypt's ratification is required for the treaty to enter into force. While a party to the NPT, Egypt's other nonproliferation commitments are rather weak.

Assessment

Although Egypt has a legitimate justification for nuclear energy and has shown few signs of interest in nuclear weapons since it ratified the NPT in 1981, it is hardly a model for nonproliferation in the Middle East. The possibility that Egypt desires a latent weapons capability cannot be dismissed entirely, in large part because it seems to be holding out from many aspects of the nonproliferation regime on the basis of claims that it is discriminatory. Even if a nuclear-armed Iran becomes a reality in the Middle East in the coming years, however, it seems unlikely that Egypt would follow suit based on its restraint in doing so vis-à-vis Israel's nuclear arsenal. The arguments that Egypt's nuclear energy ambitions are a response to Iran's are rarely made with evidence to support the claim, such as one article claiming that, "Egypt's announcement last September that it will revive its dormant nuclear program...is a direct consequence of Iran's budding nuclear program and the international community's inability to stop it."³⁵¹ Throughout the article the only evidence to support that statement was commentary from an Egyptian security analyst rather than an analysis of nuclear decision-making and government

³⁴⁹ Bereng Mtimkulu, "Africa bans the bomb (Treaty of Pelindaba signed)," *Bulletin of the Atomic Scientists* (July 1996).

³⁵⁰ Jan Prawitz and James F. Leonard, *A Zone Free of Weapons of Mass Destruction in the Middle East* (New York: United Nations, 1996).

³⁵¹ Salama and Weber, 44.

motives. Arguments that Egypt would respond to Iranian nuclear weapons with a program of its own are so far not well-developed, and need to be more convincingly argued before they can be credibly used to conclude that Egypt's nuclear energy ambitions are partially the result of a desire for a nuclear weapons option.

Saudi Arabia

Unlike Egypt and Iran, Saudi Arabia's interest in nuclear energy is a new development, so the country's nuclear history is short and less complicated than many of its Middle Eastern neighbours. Saudi Arabia is a member of the Gulf Cooperation Council (GCC) and its nuclear plans largely depend on the success of the regional nuclear project announced by the GCC in 2006. Current concerns about Saudi Arabia revolve around its relationship with Iran and how the largest Sunni state would react in the face of a potentially nuclear-armed, Shi'a dominated Iran.

Gulf Cooperation Council nuclear project

Saudi nuclear plans involve a project with the other five Gulf States—Bahrain, Kuwait, Oman, Qatar and the UAE—for regional cooperation on a nuclear power plant project. At a summit in Riyadh in December 2006 the Gulf States agreed to conduct feasibility studies with the aim of bringing nuclear power to the region.³⁵² GCC Secretary General Abderrahman Al-Attiyya stated in 2006 that the GCC hoped to begin construction in 2009³⁵³, but as of October 2009 the GCC has not yet sorted out the details of how the arrangement between the Gulf States would work, including where the plant

³⁵² Richard Weitz, "Gulf Cooperation Council Moves Forward with Energy Plans," *WMD Insights* (April 2007), http://wmdinsights.com/I14/I14_ME3_GCCMovesForward.htm (accessed 11 August 2009).

³⁵³ Weitz.

would be located. One IAEA statement concluded that, “Within the GCC, thus far there has been little coordination or effective cooperation in setting up a nuclear power program benefitting member states.”³⁵⁴ A GCC nuclear project seems many years if not decades away from materializing in the form of a nuclear power plant for the region.

The Gulf nuclear project does not pose much of a proliferation risk as currently outlined by the GCC. The IISS study concludes that, “There is no indication that the GCC states plan to develop any sensitive fuel-cycle facilities of their own, and the lack of local expertise would probably preclude work on parallel secret nuclear-weapons programmes.”³⁵⁵ A potential benefit of the cooperative project—depending on what form the project ultimately takes—is that the Gulf States would theoretically hold each other in check thereby preventing one state from misusing the nuclear infrastructure set up as a result of it. On the other hand, the project has been criticized as being motivated by the Iranian nuclear program rather than a legitimate need for nuclear energy. The same study, for example, criticizes the GCC’s nuclear aspirations “as being intended as a demonstration of technical parity with Iran and as a security hedge – that is, to enhance Gulf States’ nuclear expertise and build up an infrastructure as a first step towards developing a nuclear-weapons capability, if desired, in the future.”³⁵⁶ The lack of progress on the project, the IAEA questioning the GCC’s seriousness and the timing of the announcement on the heels of Iran restarting uranium enrichment suggest that the announcement may have been a demonstration for Iran’s benefit rather than a legitimate desire for nuclear energy. Ultimately the project is moving forward at a slow pace and

³⁵⁴ Mark Hibbs, “Persian gulf states not expected to decide quickly on power reactors,” *Nucleonics Week* 49:4 (2008).

³⁵⁵ IISS, 36.

³⁵⁶ IISS, 36.

may not succeed at all, so any possible proliferation risks are not likely to materialize soon.

Justifications for nuclear energy

If there is one state lacking a justification for nuclear energy in the Middle East it would probably be Saudi Arabia. Saudi Arabia is the world's second largest producer of oil, is home to 25 percent of the world's oil reserves and is the ninth biggest producer of natural gas, all of which it consumes domestically.³⁵⁷ All of the country's primary energy consumption is currently from fossil fuels.³⁵⁸ Saudi Arabia's apparent need for nuclear energy is for water desalination due to its poor fresh water access, but desalination is already occurring using natural gas fired plants.³⁵⁹ While nuclear can provide a clean alternative to natural gas, the country still lacks the expertise and infrastructure to do so in the short-term, especially at a cost comparable to the natural gas desalination plants the country has already been building. Some critics have also pointed out that Saudi Arabia is a prime candidate for solar power given the 300 or more days of sunlight the country gets in a year.³⁶⁰ For an energy-rich country like Saudi Arabia nuclear power seems an especially odd choice, although there has been little indication so far that the country is seriously pursuing those plans. Saudi Minister for Water and Electricity did announce in August 2009 that the country has interest in developing a nuclear power plant, but no

³⁵⁷ Central Intelligence Agency, "The World Factbook: Saudi Arabia," <https://www.cia.gov/library/publications/the-world-factbook/geos/sa.html> (accessed 11 August 2009).

³⁵⁸ British Petroleum Company, 41.

³⁵⁹ Windsor and Kessler, 80.

³⁶⁰ Edward J. Markey, "Why Is Bush Helping Saudi Arabia Build Nukes?" *The Wall Street Journal*, 10 June 2008, <http://online.wsj.com/article/SB121305642257659301.html> (accessed 11 August 2009).

plans have been proposed.³⁶¹ The fate of nuclear power in Saudi Arabia may come down to how determined the GCC is in succeeding with its nuclear power ambitions, and how much value the Gulf States put on counter-balancing the Iranian nuclear program with a peaceful program of their own.

Nuclear weapons history and prospects

Saudi Arabia has never been proven to have pursued nuclear weapons so its nuclear weapons history is limited to some speculation and its relationship with Iran. Most of the speculation about possible past Saudi weapons activities derive from one source—former Saudi diplomat Mohammed al Khilewi. Khilewi claimed that Saudi Arabia attempted to build nuclear arms, funded Saddam Hussein’s nuclear weapons program in Iraq and attempted to buy nuclear weapons from Pakistan.³⁶² He provided documents to support his claims but the Saudi government insisted they were forgeries. None of Khilewi’s claims have been supported with anything but circumstantial evidence without much bearing, so they have mostly been dismissed. Saudi Arabia lacks nuclear expertise and a nuclear infrastructure aside from a few nuclear-related science labs and university programs in fields not considered dual-use, so domestic nuclear weapons pursuit seems highly unlikely.³⁶³ The claim that the Saudis were funding the Iraqi program in return for nuclear weapons of their own was never independently verified, and is not considered substantive.³⁶⁴ Saudi Arabia does have a security relationship with Pakistan including an arms trade, and Pakistani scientist Abdul Qadeer Khan did visit Saudi Arabia in

³⁶¹ “Saudis set stage for Mid-East nuke race,” *The Australian*, 22 August 2009, <http://www.theaustralian.news.com.au/story/0,25197,25963207-15084,00.html> (accessed 29 September 2009).

³⁶² Windsor and Kessler, 87.

³⁶³ Windsor and Kessler, 81-84.

³⁶⁴ Windsor and Kessler, 87-88

November 1999, there is no confirmation that Saudi Arabia ever attempted to acquire a weapon from the Pakistani government or nuclear technology from Khan.³⁶⁵

Dialogue about nuclear weapons and Saudi Arabia now centres on Iran. As the largest Sunni state in the region, Saudi Arabia is competing with Shi'a dominated Iran in claiming leadership over the global Islamic community.³⁶⁶ Saudi Arabia's rivalry with Iran has not, however, driven the Saudis to seriously contemplate nuclear weapons based on publically available information. A report by *The Guardian* that Saudi leaders discussed acquiring nuclear weapons as a possible response to the Iranian nuclear program in 2003 was denied by Saudi officials, and in any case the Saudis do not appear to have taken any steps towards doing so.³⁶⁷ Part of the reason for not responding in kind to the Iranian program is that Saudi citizens—and indeed Gulf citizens generally—do not feel directly threatened by Iran. In a 2006 poll asking Arab respondents which two countries posed the greatest threat to them, 85 percent chose Israel, 72 percent chose the US and only 11 percent chose Iran, with a majority of respondents supportive of the Iranian nuclear program.³⁶⁸ Although the US invasion of Iraq shifted the balance of power in the Middle East in Iran's favour, the Gulf States have had little involvement in negotiations aimed at stopping or slowing Iran's nuclear program.³⁶⁹ The Gulf States' absence in dealing with Iran seems counter-intuitive, but is—according to one study—likely based on beliefs that the Iranian nuclear program is a threat aimed at Israel and the

³⁶⁵ IISS, 43.

³⁶⁶ "Will Saudi Arabia Acquire Nuclear Weapons?" Nuclear Threat Initiative, http://www.nti.org/e_research/e3_40a.html (accessed 12 August 2009).

³⁶⁷ Ewen MacAskill and Ian Traynor, "Saudis consider nuclear bomb," *The Guardian*, 18 September 2003, <http://www.guardian.co.uk/world/2003/sep/18/nuclear.saudiarabia> (accessed 12 August 2009).

³⁶⁸ IISS, 39.

³⁶⁹ El-Hokayem and Legrenzi, 8.

US rather than them.³⁷⁰ The security consequences of possible Iranian nuclear weapons are profound for Saudi Arabia, but not enough that the country would stand to benefit from pursuing nuclear weapons of its own, particularly given its close political and economic ties with the US. The US and Saudi Arabia did nearly USD 67 billion in trade in 2008, after all.³⁷¹ Furthermore, when Saudi Arabia was under threat of invasion during the First Gulf War the US was quick to provide protection in the form of military support, including some 500,000 troops stationed in Saudi Arabia in preparation for the liberation of Kuwait.³⁷²

Nonproliferation disposition

Saudi Arabia's interest in nuclear technology is relatively new, so like the other Gulf States it is just beginning to establish itself in the nonproliferation regime. Whether the Saudis intend to adhere to the highest standards of nonproliferation—an Additional Protocol in particular—or to reject them remains unknown. Saudi Arabia ratified the NPT in 1988, but its Comprehensive Safeguards Agreement just came into force on 13 January 2009. The Saudis have opted to forego sensitive fuel cycle technology as a part of their nuclear program, as detailed in a Memorandum of Understanding (MOU) on nuclear cooperation between Saudi Arabia and the US.³⁷³ As Saudi Foreign Minister Prince Saud Al-Faisal said, the GCC nuclear project “is not a threat...It is an announcement so that there will be no misinterpretation of what we are doing. We are not doing this secretly.

³⁷⁰ El-Hokayem and Legrenzi, 10.

³⁷¹ U.S. Census Bureau, “Foreign Trade Statistics,” <http://www.census.gov/foreign-trade/balance/c5170.html#2009> (accessed 30 September 2009).

³⁷² Madawi Al-Rasheed, *A History of Saudi Arabia* (Cambridge: Cambridge University Press, 2002): 163-165.

³⁷³ “Saudi makes promises in US cooperation agreement,” *World Nuclear News*, 19 May 2008.

We are doing it openly.”³⁷⁴ So far there is no evidence to suggest the Saudi claims should be doubted. Saudi Arabia has not signed an Additional Protocol, but its nuclear ambitions are still in their infancy and its CSA has just entered into force. Given Saudi interest in cooperating with the US in its nuclear ambitions and the Obama administration’s de facto policy of requiring an Additional Protocol for nuclear cooperation, it seems likely it is only a matter of time before Saudi Arabia does sign one if it is serious about moving forward with its nuclear plans.³⁷⁵

Saudi Arabia’s close ties with the US—despite a cooling of relations from around 2005 onward—predispose it towards good nonproliferation credentials, and the Saudi-US relationship may indeed be the most important consideration in assessing the proliferation risk of the country.³⁷⁶ Saudi leaders furthermore are not likely to be willing to risk the political and economic backlash of attempting to acquire nuclear weapons “at a time when they are trying to integrate more into the international economy.”³⁷⁷ Saudi nuclear weapons would severely strain Saudi-US relations and Saudi leadership are well aware that they likely derive more benefit—politically and economically, if not militarily—from the US as an ally than they would an indigenous nuclear arsenal.³⁷⁸ The political and economic consequences of pursuing nuclear weapons are likely more than King Abdullah would be willing to bear.

One point of contention regarding Saudi commitment to the safeguards regime was its request to sign a Small Quantities Protocol (SQP) to free it of many of its safeguards commitments under a CSA—a request the IAEA approved in 2005. While Saudi Arabia

³⁷⁴ “Nuclear energy is needed: Saudi Cabinet,” *Arab News*, 12 December 2006.

³⁷⁵ Private discussion with US Department of State official, US Department of State (Washington DC: April 2009).

³⁷⁶ “Will Saudi Arabia Acquire Nuclear Weapons?”

³⁷⁷ “Will Saudi Arabia Acquire Nuclear Weapons?”

³⁷⁸ Richard L. Russell, “A Saudi Nuclear Option?” *Survival* 43:2 (2001): 70-71, 72-75.

does not have a domestic enrichment or reprocessing capability to fabricate material for a nuclear weapon, why a state with supposed nuclear power ambitions would opt to implement a protocol intended for states with minimal interest in nuclear technology is baffling.³⁷⁹ The IAEA Board of Governors in fact amended the SQP to increase reporting requirements and reinstate the Agency's right to inspect facilities in 2005 precisely because certain member states expressed concern that it was a potential proliferation loophole.³⁸⁰ Saudi Arabia has not since replaced its original SQP with the revised one. Saudi Arabia's SQP is likely a reflection of the state not taking its nuclear plans through the GCC seriously and trying to avoid safeguards measures it feels are unnecessary given the limited scope of its nuclear activities, at least for the time being. On the other hand, concerns that the GCC plans are intended as a "hedge" against the Iranian program could suggest the Saudi SQP is of proliferation concern. The signing of the SQP alone is not necessarily indicative of any nefarious intent by Saudi Arabia, but it does raise questions about the seriousness of Saudi nuclear energy plans.

Assessment

Saudi Arabia does not appear to be on a potential path towards nuclear proliferation and is at worst a minimal risk. The country's existing nuclear capacity is meek and its nuclear plans are modest, involving only a cooperative nuclear project that specifically excludes enrichment or reprocessing. Saudi Arabia is lacking a legitimate economic or energy security justification for nuclear energy, but it has taken little initiative outside of the GCC project—and indeed little within it—indicating that it probably does not intend

³⁷⁹ Pojedinec.

³⁸⁰ "Board Moves to Strengthen Nuclear Safeguards System," *International Atomic Energy Agency*, 23 September 2005, http://www.iaea.org/NewsCenter/News/2005/strengthening_sg.html (accessed 12 August 2009).

to acquire a latent capability in the process. The Saudi relationship with the US, and its increasing integration into the international economy, increase the cost of Saudi non-compliance with the NPT and further decrease the probability of nuclear weapons motivations. It is the country's strategic relationship with Iran and the possibility that its security relationship with the US will deteriorate further that raises some concern about potential motivations for a nuclear weapons option. Barring any drastic changes in Saudi-Iranian relations or Saudi-US relations the chances of King Abdullah—or his successors—pursuing nuclear weapons are remote. Saudi Arabia is, moreover, still decades away from the technical capability to develop them indigenously. The risk that Saudi Arabia is pursuing nuclear energy for a weapons capability is therefore remote.

United Arab Emirates

The UAE, another GCC member state, is the most likely state—other than Iran—in the Middle East to successfully implement nuclear power because of its wealth and the relationships it is establishing with major nuclear suppliers. Although the UAE meets the criteria of a “high proliferation risk state” set out in the previous chapter—notably it has not yet ratified an Additional Protocol, is not protected by a positive security guarantee and there is a nuclear-armed state in the region, in addition to it having a SQP in force—it is currently taking steps that would preclude it from the list. Not only is the UAE in the process of upgrading its nonproliferation credentials to meet the highest standards, but it is trying to establish itself as a model for nonproliferation in the Middle East—a

description that has been repeated by senior US officials.³⁸¹ The UAE is unique in the Middle East in that it is, as its name indicates, a union of emirates that lacks a strong national identity.³⁸² The UAE's formation was an effort to cope with the withdrawal of British influence and protection in the region during the period of rapid decolonization in the 1960s.³⁸³ While the UAE does have a federal government with near-total control over the conduct of foreign affairs, its constitution relegates authority over various domestic issues, including control over wealth and resources, to the various territories.³⁸⁴ The UAE's governance structure and composition of its population—notably diverse indigenous tribes and high proportion of immigrants—are atypical for a Middle Eastern country, and the UAE has partially as a result of these factors focused more on generating wealth than on foreign affairs.³⁸⁵ Unlike the other states examined, the UAE appears to be doing everything in its power to reassure the rest of the world that its nuclear ambitions are unequivocally peaceful.

Justification for nuclear energy

Although the UAE has the world's sixth largest proven oil reserves and fifth largest proven natural gas reserves³⁸⁶, it has been making a strong economic case for why it would benefit from nuclear energy. Foreign Minister Shaikh Abdullah Bin Zayed Al Nahyan stated "The UAE's rapid economic growth and a predicted shortage in natural

³⁸¹ "UAE Pact Could Become Basis for Future Nuclear Deals, Experts Say," *Global Security Newswire*, 3 February 2009.

³⁸² Ali Mohammed Khalifa, *The United Arab Emirates: Unity in Fragmentation* (Boulder: Westview Press, 1979).

³⁸³ Christopher M. Davidson, *The United Arab Emirates: A Study in Survival* (Boulder: Lynne Rienner Publishers, Inc., 2005): 45-53.

³⁸⁴ Khalifa, 40-41.

³⁸⁵ Davidson, 293-300.

³⁸⁶ Central Intelligence Agency, "The World Factbook: United Arab Emirates," <https://www.cia.gov/library/publications/the-world-factbook/geos/ae.html> (accessed 12 August 2009).

gas calls for diversifying the country's energy sources."³⁸⁷ The UAE has an existing electrical grid capacity of approximately 16,000 MW, but analysis has shown that by 2020 peak demand will reach nearly 41,000 MW, a 156 percent increase in just over a decade.³⁸⁸ Fresh water resources are extremely limited in the UAE requiring large-scale water desalination projects that require considerable amounts of energy, including plans to build a 9,000 MW desalination complex in Dubai.³⁸⁹ By generating electricity using nuclear power, the UAE can also export more oil and natural gas instead of using it for domestic consumption.³⁹⁰ A combination of rapidly increasing electricity demand, the high power requirements of massive planned desalination projects and the desire to diversify its energy sources has led the UAE to begin its pursuit of nuclear power. One discrepancy is—according to a study of technical nuclear capabilities in the Middle East—that the UAE is still “several decades” away from generating nuclear power because it lacks a sufficient technical and legislative framework for a nuclear program.³⁹¹ The country will therefore have difficulty meeting its projected energy demand using nuclear power.

Another reason nuclear energy seems a legitimate pursuit in the UAE is that the decision to invest in nuclear power was the result of a process that included the possibility of other energy alternatives. The UAE determined that nuclear power was the only energy option with the potential to meet its rapidly increasing demand. A UAE white paper

³⁸⁷ “UAE to set up Emirates Nuclear Energy Corporation,” *Gulf News* 21 April 2008, <http://www.gulfnews.com/nation/Government/10207145.html> (accessed 12 August 2009).

³⁸⁸ “Nuclear matters,” *Gulf News*, 31 July 2008, <http://www.gulfnews.com/business/General/10233061.html> (accessed 12 August 2009).

³⁸⁹ Windsor and Kessler, 124.

³⁹⁰ “UAE launches nuclear policy to meet energy demand,” *World Nuclear News*, 14 July 2008, http://www.world-nuclear-news.org/NP-UAE_launches_nuclear_policy_to_meet_energy_demand-1407086.html (accessed 12 August 2009).

³⁹¹ Windsor and Kessler, 130.

examined in depth several energy options finding that alternatives were not the best option for the scale the UAE required:

*Evaluation of alternative energy sources, including solar and wind power, suggested that, while these options could be deployed within the UAE, even aggressive deployment could only supply 6 to 7% of peak electricity demand by 2020.*³⁹²

The UAE nuclear decision was not made without due consideration for alternatives as it has been in other states³⁹³, but was the result of a deliberate study of energy options. The main criticism of nuclear energy—that its upfront costs are too high—is less of a problem for the UAE due to the country’s wealth. The UAE’s GDP per capita of USD 40,000³⁹⁴ is the nineteenth highest in the world—higher than countries with advanced nuclear industries such as Canada, Japan and the UK.³⁹⁵ The country’s estimate for each nuclear power plant of USD 7 billion each indicates that the country is fully aware of the costs of nuclear power plants and is willing to assume them.³⁹⁶ The UAE is one of few aspiring nuclear energy states that has fully considered the costs and benefits of nuclear power and has decided to proceed with its plans based on that analysis. Despite the country’s fossil fuel reserves, it seems serious about using nuclear power to help it meet its future energy needs.

Nuclear weapons history and prospects

The UAE has never been suspected of pursuing nuclear weapons, but it has been criticized for being a hub for the illicit transfer of nuclear technology in the past. Iran

³⁹² “UAE to set up Emirates...”

³⁹³ Nuclear Energy Futures Project.

³⁹⁴ Based on purchasing power parity.

³⁹⁵ Central Intelligence Agency, “The World Factbook: GDP – Per Capita (PPP),” [https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html?countryName=United Arab Emirates&countryCode=ae®ionCode=me&rank=19#ae](https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html?countryName=United+Arab+Emirates&countryCode=ae®ionCode=me&rank=19#ae) (accessed 12 August 2009).

³⁹⁶ “Nuclear matters.”

used UAE ports to “evade international restrictions by transshipping goods from there” and AQ Khan “relied on the UAE as a key hub in assisting clandestine uranium-enrichment programs in Iran and Libya.”³⁹⁷ The UAE is indeed a major hub for all trade in the Middle East because of its geographical location, so its status as a hub for illicit transfers of nuclear technology is the result of poor controls and to some extent complicity rather than ill intent.³⁹⁸ In May 2005 the UAE joined the US National Nuclear Security Administration’s Megaports Initiative, a program that seeks to deter nuclear terrorists by equipping seaports with radiation detection equipment.³⁹⁹ The UAE has not been accused of deliberately facilitating a nuclear black market, but its port security remains an issue of concern, particularly if the country intends to begin importing nuclear technology and material of its own. The country nonetheless seems to be taking steps towards preventing any future illicit transfers.

The UAE is less predisposed towards reacting to Iranian nuclear weapons than either Egypt or Saudi Arabia, in part because as a smaller, ethnically diverse state the country is not a religious rival for leadership of the Islamic world, nor a political rival for prominence in the Middle East. The UAE has always made efforts to have cordial relations with Iran in large part because about one-quarter of Dubai’s citizens—the wealthiest of the seven Emirates—are of Iranian descent, and Iran is the country’s largest non-oil export market.⁴⁰⁰ Tension between the UAE and Iran has therefore been limited to a border dispute over the Greater and Lesser Tumbs and part of Abu Musa dating back to

³⁹⁷ Miles Pomper, “U.S., UAE Sign Nuclear Cooperation Pact,” *Arms Control Today* (March 2009): 44.

³⁹⁸ Windsor and Kessler, 125-126.

³⁹⁹ National Nuclear Security Administration, “Megaports Initiative,” *US Department of Energy*, http://nnsa.energy.gov/nuclear_nonproliferation/1641.htm (accessed 12 August 2009); Windsor and Kessler, 126.

⁴⁰⁰ IISS, 54.

the UAE's formation in 1971.⁴⁰¹ The UAE nonetheless is not likely to have much interest in countering a potential Iranian bomb with one of its own. Although leaders of other Arab states have often left the nuclear option open in response to Iran—including Egypt and Saudi Arabia—UAE officials have made clear in no uncertain terms that UAE interest in nuclear energy “has nothing to do with Iran”⁴⁰² The UAE would indeed have little to gain from pursuing a nuclear deterrent in response to an Iranian nuclear arsenal since its relations with the pariah state are already comparably friendly than those of other Middle Eastern states.

Nonproliferation disposition

The UAE has taken or is in the process of taking all of the necessary steps towards implementing nuclear power in the country in such a way that it does not raise nonproliferation concerns, and can serve as a model for nuclear power in the Middle East.

As Foreign Minister Shaikh Abdullah put it:

*It is the UAE's hope that the final policy [decisions regarding the UAE's nuclear program] may also serve as a replicable model for non-nuclear countries to evaluate and potentially implement [a] peaceful nuclear programme with [the] full support [of] the international community.*⁴⁰³

The UAE's commitments to full transparency in its nuclear program and to forego sensitive fuel cycle technology indicate that the government is not just speaking rhetorically about being a nonproliferation model, but is taking the right steps to do so as well. Abdullah has made the following comments about transparency and sensitive fuel cycle technology:

⁴⁰¹ IISS, 53-54.

⁴⁰² “UAE Pact Could Become...”

⁴⁰³ “UAE and France sign landmark nuclear cooperation agreement,” *Gulf News*, 16 January 2008, <http://archive.gulfnews.com/articles/08/01/15/10182119.html> (accessed 14 August 2009).

*The UAE will publish the programme's full details, in keeping with its approach of absolute transparency in dealing with the international community.*⁴⁰⁴

*In an effort to limit the danger of proliferation, the UAE government has also adopted a policy renouncing the development of any domestic enrichment or reprocessing capabilities in favour of long-term arrangements for the external supply of nuclear fuel.*⁴⁰⁵

In committing to transparency and renouncing domestic enrichment and reprocessing the UAE has taken two important steps towards reassuring the international community that its program is only for peaceful energy purposes.

The UAE is included as a potential high risk proliferation state because it does not have an Additional Protocol in force and does have a Small Quantities Protocol, but unlike Egypt, Iran or Saudi Arabia the UAE is making quick progress to remove these discrepancies in its nonproliferation credentials. The UAE's interest in nuclear energy is new, so it just recently completed its CSA with the IAEA in October 2003 after ratifying the NPT in 1995.⁴⁰⁶ The IAEA Board of Governors approved an Additional Protocol for the UAE on 3 March 2009, and the UAE signed it on 9 April 2009.⁴⁰⁷ Unlike Iran—which signed an Additional Protocol in December 2003 and indicates that it has no intention of implementing it—UAE officials have given every indication, such as the statements quoted above, that they fully intend to implement the agreement. Once the Additional Protocol comes into force it will render the UAE's Small Quantities Protocol obsolete, but the UAE has agreed to terminate its SQP in nuclear cooperation agreements

⁴⁰⁴ "UAE will be the first Gulf state to develop civilian nuclear power," *Gulf News*, 24 March 2008, <http://www.gulfnews.com/nation/Government/10199888.html> (accessed 14 August 2009).

⁴⁰⁵ "U.S. Signs Nuclear Deal With United Arab Emirates," *Global Security Newswire*, 21 April 2008, http://www.globalsecuritynewswire.org/gsn/GSN_20080421_A77956A2.php (accessed 14 August 2009).

⁴⁰⁶ International Atomic Energy Agency, "Safeguards Current Status," http://www.iaea.org/OurWork/SV/Safeguards/sir_table.pdf (accessed 14 August 2009).

⁴⁰⁷ International Atomic Energy Agency, "Strengthened Safeguards System: Status of Additional Protocols," http://www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html (accessed 14 August 2009).

it has made as a condition of supply anyway.⁴⁰⁸ Although as of August 2009 the UAE still has some work to do before its legal obligations are up to par, there is little doubt that it will agree to the highest safeguards standards currently practiced.

One highly lauded step the UAE took was to sign a groundbreaking nuclear cooperation agreement with the United States. The agreement includes measures by which the US can terminate it if the UAE changes course and decides to pursue enrichment or reprocessing technology.⁴⁰⁹ It requires that the UAE have an Additional Protocol in force before any transfers of technology can occur.⁴¹⁰ Beyond the requirements the agreement makes of the UAE, it also commits the US to negotiating equally as strict agreements with other states in the region, or the UAE has to be offered a less strict agreement as well.⁴¹¹ The US-UAE nuclear cooperation agreement therefore not only requires that the UAE commit to the highest nonproliferation standards, but has some bearing on how other nuclear agreements—at least with the US for now—are constructed in the Middle East. Perhaps a greater contribution of the agreement to nonproliferation is that it is a model for how to limit the spread of enrichment and reprocessing technology to new states in a more nuanced and practical way than adopting a universal policy of no new enrichment or reprocessing states—an approach that has drawn criticism from countries with an interest in domestic enrichment like Canada.⁴¹² If other states choose to follow a similar path towards nuclear energy as the UAE has so far,

⁴⁰⁸ Christopher M Blanchard and Paul K Kerr, “The United Arab Emirates Nuclear Program and Proposed U.S. Nuclear Cooperation,” (Washington: Congressional Research Service, 2009): 11-12.

⁴⁰⁹ “Agreement for Cooperation Between the Government of the United Arab Emirates and the Government of the United States of America Concerning Peaceful Uses of Nuclear Energy,” <http://www.npec-web.org/us-uae/20090115-USUae-Revised123Agreement.pdf> (accessed 14 August 2009): 10.

⁴¹⁰ “Agreement for the Cooperation Between...” 12-14.

⁴¹¹ “Agreement for the Cooperation Between...” 26-27.

⁴¹² Private conversation with US Department of State official, US Department of State, (Washington, DC: April 2009).

its decision to pursue peaceful nuclear technology could be of net benefit to nonproliferation rather than increased risk.

Assessment

The UAE rightfully does not belong alongside Egypt and Saudi Arabia as a high proliferation risk state. Although its Additional Protocol has not yet entered into force and it is located in a potentially volatile region for nuclear weapons, the UAE is a highly unlikely candidate for wanting a latent weapons capability. It is making progress towards implementing an Additional Protocol and is going to great lengths to ensure that its nuclear ambitions are perceived by the rest of the world as exclusively peaceful. It has virtually no nuclear weapons history—aside from past concerns about complacency in smuggling nuclear technology—and does not seem likely to react to an Iranian nuclear weapon with a weapons program of its own. Given its lack of existing nuclear infrastructure, the UAE is several decades from having the capability to build nuclear weapons and is so far depending on skilled workers mainly from Western countries to do so.⁴¹³ The UAE is in all likelihood not motivated at all by acquiring a latent weapons capability or nuclear weapons.

⁴¹³ Private conversation with US Department of State official, US Department of State, (Washington, DC: April 2009).

Conclusion

Research outcome

A two-part question was posed at the beginning of this research: are states aspiring to nuclear energy for the first time as a part of the purported nuclear revival doing so with the intention of acquiring a nuclear weapons option, and does the nuclear revival as a result involve a high risk of nuclear proliferation? The following conclusions can be drawn from the research.

The technical connection between nuclear energy and weapons

While a peaceful nuclear energy program does not provide a state with all of the applications required to acquire weapons-grade material or design and build a nuclear weapon, it does provide scientific capacity, expertise, technology and infrastructure that can be exploited for weapons purposes. It can also provide camouflage for clandestine weapons activities. There is therefore an inherent risk in the spread of nuclear power, but only if the states it spreads to are also motivated to pursue nuclear weapons.

Global survey of proliferation risk

Risk is a measure of two variables: technological capacity and intention. Most aspiring nuclear energy states do not seem to have the capacity—especially in terms of their physical infrastructure and economic resources—to implement nuclear energy before 2030, and in some cases well beyond. Even using generous minimums for installed electrical capacity, GDP and credit ratings, 14 of the 29 aspiring states are particularly unlikely to succeed in their nuclear power ambitions. Many aspiring states' nuclear

ambitions will not translate into proliferation risk because they are not likely able to acquire nuclear power. These states cannot be precluded from being motivated by nuclear weapons, but nuclear power is not a credible path for them to acquire the bomb.

Based on proliferation risk indicators drawn from theories of proliferation, most potential nuclear energy states do not appear to be predisposed towards pursuing nuclear weapons. Only three states—Egypt, Saudi Arabia and the UAE—qualified as potential high risk states. The criteria chosen determined that all of the potential high proliferation risk states are located in the Middle East, reaffirming the common conception and historical evidence that the Middle East is a potentially proliferation-prone region.

Potentially high risk states

The proliferation risk of Egypt, Saudi Arabia and the UAE varied between each state. An assessment based on justifications for nuclear energy, past experiences with nuclear weapons and nuclear weapon states and nonproliferation credentials determined the following:

- **Egypt** does not appear to be interested in continuing its efforts to acquire nuclear power for a latent nuclear weapons capability, although its concerns about Iran and Israel may suggest otherwise. Egypt has, however, given no signs that it intends to pursue nuclear weapons since joining the NPT in 1981. Furthermore, during its years of violent conflict with nuclear-armed Israel, Egypt did not have a well-developed nuclear weapons program, despite some research activities, suggesting it is unlikely to respond in to a nuclear-armed Iran with a weapons program of its own.
- **Saudi Arabia** has only modest nuclear energy ambitions primarily through the Gulf Cooperation Council, so the risk of a latent capability motivation is limited by the cooperative nature of the project. Its close political and economic ties with the United States and increasing integration into the global economy also raise the cost of pursuing nuclear weapons for the state, making it an unlikely proliferation risk.
- **United Arab Emirates** is intent on becoming a model for the introduction of nuclear energy into the Middle East. It appears committed to transparency and

high nonproliferation standards, and is likely only months away from having an Additional Protocol in force, which would preclude it from this group of high risk states. The UAE is nearly of no proliferation risk, and indeed may even further the cause of nonproliferation in the Middle East if others do see it as a model.

The outcome of this research is therefore that states are not likely pursuing nuclear power with the intention of acquiring a latent nuclear weapons capability, but rather other cited benefits of nuclear energy. Although the spread of nuclear energy will mean greater capacities for nuclear weapons development, states do not seem to be engaging in nuclear hedging.

Closing remarks

In the history of nuclear weapons, political leaders, policymakers, intelligence officials and proliferation experts have had the arduous task of staying one step ahead of potential would-be proliferators. Preventing nuclear proliferation before it occurs—be it using incentives, establishing norms or coercion—has proven to be a more effective strategy than trying to reverse it after the fact. The NPT was a monumental achievement in establishing a global order that stigmatizes states that decide to go nuclear. The challenge of nuclear nonproliferation has as a result been to determine and isolate those rare states with the inclination to risk the backlash of the international community and pursue weapons anyway. It is important that those working in the field remain vigilant of the potential nuclear weapons aspirations of states so that action can be taken to dissuade or prevent them from succeeding. More importantly, however, by learning what drives states to forego their international legal obligations and risk ostracizing themselves we can be better equipped to address the root causes of proliferation.

The importance placed on preventing nuclear proliferation and understanding what motivates it has, however, led to a tendency in the arms control field to exaggerate the risks of nuclear proliferation. In a 1994 article in the *Bulletin of the Atomic Scientists* article, William Arkin dubbed the nuclear nonproliferation field “the sky-is-still-falling profession.”⁴¹⁴ His assessment was based on rising concerns in the aftermath of the Cold War that these weapons spreading to new states was now the great nuclear threat rather than the massive Soviet arsenal, claims Arkin feels derived from “Cold Warriors” intent on keeping their profession interesting and relevant. In the article, Arkin recounts several “threats” that appeared to be looming in 1994:

*North Korea and the United States struck a deal to inspect seven of the North's nuclear sites. Not good enough, sceptics said; the North's real strategy is to focus attention away from mountain hideaways that contain the true jewels. The [US] intelligence community “believes” that the North has the materials to make them, and therefore **must** have them.*

Iraq reaches the end of the most comprehensive and intrusive disarmament scheme ever by the U.N. Special Commission. Not certifiably clean, some continue to claim; it is concealing an underground plutonium reactor—and besides there is still the knowledge of the bomb. Meanwhile, Iran extends an open-door invitation to the International Atomic Energy Agency to inspect any site on its territory. We believe, says the State Department's head of nonproliferation, that the Iranians are still secretly pursuing the bomb, even if there is no evidence to prove it.⁴¹⁵

As it turns out Arkin's criticisms reveal both the importance of constant vigilance as well as the consequences of exaggeration. North Korea was pursuing nuclear weapons despite the deal, a feat it accomplished with its October 2006 nuclear test, and new information has revealed that Iran did seem to pursue the bomb in the 1990s until at least as late as 2003. On the other hand, fear about Saddam Hussein's alleged ongoing weapons efforts

⁴¹⁴ William Arkin, “The sky-is-still-falling profession,” *Bulletin of the Atomic Scientists* 50:2 (March 1994): 64.

⁴¹⁵ Arkin, 64.

after the First Gulf War became the rallying cry of the 2003 US invasion of Iraq—an invasion considered illegitimate if not illegal by many given that US evidence was not only false, but in some cases fabricated. It is imperative in the arms control profession that the right balance is struck between being wary of possible threats and determining when those possible threats become tangible enough that they should be acted upon, particularly if military force is the action of choice.

Introducing nuclear energy into this balance complicates it further because divining state intentions becomes more challenging given often legitimate justifications for nuclear power. The bottom line is that ultimately no matter how well justified a state's nuclear aspirations may be, the possibility that it may desire a peaceful nuclear program in order to build up the scientific capacity, expertise and infrastructure to obtain the capability for an eventual nuclear weapons program cannot be ruled out entirely. A state using its peaceful nuclear program as camouflage for illicit weapons activities is an inherent risk in the spread of nuclear technology. This reality is what has led to some experts crying foul about introducing nuclear energy into volatile regions, and the Middle East especially. The possibility that an aspiring nuclear energy state will divert some of its nuclear resources to a weapons program is not, however, enough for nuclear suppliers and the IAEA to justify denying technology to certain states. Technological capability is only one part of the equation and needs to be considered alongside demand for nuclear weapons. States will only exploit their peaceful nuclear infrastructures if they are motivated to acquire nuclear weapons. Remove the motivation and the problem is likely to go away. The challenge that the purported nuclear revival presents to the nuclear nonproliferation regime is nonetheless essentially the same challenge it has faced for decades—detecting and dealing with rare cases of noncompliance.

The purported nuclear revival does not change the proliferation problem posed by nuclear weapons. It is not likely to result in a “cascade” of nuclear proliferation, nor does it seem likely that other Middle Eastern states will respond in kind if Iran chooses to build a nuclear weapon. The nuclear proliferation challenges that the world faces are those that have already been identified by relevant stakeholders. North Korea detonated its second nuclear weapon on 25 May 2009 and is undergoing internal changes as Kim Jong-Il solidifies his third son as his successor, so there is a lot of uncertainty about what its nuclear intentions are and how they will unfold during this time of transition. Syria is reported to have been building a secret nuclear facility—that US reports claim was being supported by North Korea—that was bombed by Israel in October 2007. Myanmar is the most recent addition, having been suspected in July 2009 of receiving nuclear-related shipments from North Korea. These states, along with Iran, are the serious nonproliferation issues of the day and should continue to be the focus of international efforts to curb proliferation. New nuclear energy states are—with the exception of Iran—not likely to be the proliferation issues of the future.

New nuclear energy programs nonetheless need to be fully safeguarded and as transparent as possible. Many states are voluntarily agreeing to stricter nonproliferation standards—embodied primarily in the Additional Protocol—but the Protocol is not required under the NPT. Efforts need to continue to ensure that the IAEA has the authority to detect clandestine nuclear activities as early as possible. Enrichment and reprocessing technologies are also not forbidden by the NPT, so creative solutions are necessary to limit their unnecessary spread without invoking outcries of discrimination from states interested in the technologies. The Achilles’ heel of the nonproliferation regime has always been that it does not include effective enforcement mechanisms,

whatever they may be. When and how to enforce compliance has instead been on an ad hoc basis—necessarily so—and actions have included economic sanctions, targeted strikes of nuclear facilities and Security Council-mandated decommissioning initiatives among others. These enforcement options—while often criticized as being ineffective—are another disincentive for states to pursue nuclear weapons and undoubtedly factor into their calculations when deciding to. Given the daunting task of acquiring a peaceful nuclear infrastructure, exploiting it to undertake secretive weapons work undetected and then facing the potential political, economic and security consequences if caught, it is no small wonder that the vast majority of aspiring nuclear energy states appear to have little to no interest in pursuing nuclear weapons.

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