DIIS REPORT

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Cindy Vestergaard

Governing Uranium Globally

DIIS Report 2015:09

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Cindy Vestergaard, Senior researcher, DIIS

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List of Abbreviations

AA	Administrative Arrangement
ABACC	Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
AEC	Atomic Energy Commission (USA)
AP	Additional Protocol
AONM	Australian Obligated Nuclear Material
ASNO	Australian Safeguards and Non-Proliferation Office
AUAM	Advanced Uranium Asset Management (Before Uranium Asset Management (UAM))
BNFL	British Nuclear Fuel Ltd
BOG	IAEA Board of Governors
BWR	Boiling Water Reactor
CAEA	China Atomic Energy Authority
CDA	Combined Development Agency (Before the Combines Development Trust (CDT))
CDT	Combined Development Trust (Later Combined Development Agency (CDA))
CEA	Commissariat à l'Energie Atomique
CGN	China General Nuclear Power Corporation
CGN-NFC	CGN Fuel Co Ltd
CNEIC	China Nuclear Energy Industry Corporation
CNEN	Brazil's National Nuclear Energy Commission (Comissão Nacional de Energia Nuclear)
CNNC	China National Nuclear Corporation
CNRS	Centre National de la Recherche Scientifique
CNSC	Canadian Nuclear Safety Commission
COOs	Civilian Owner/Operators
CPPNM	Convention on the Physical Protection of Nuclear Materials
CSA	Comprehensive Safeguard Agreement
DPRK	Democratic People Republic of Korea

DRC	Democratic Republic of Congo
DU	depleted uranium
EDF	Électricité de France
ERA	Energy Resources Australia
ESA	European Supply Agency
EUP	enriched uranium product
IAEA	International Atomic Energy Agency
ICAO	International Civil Aviation Organization
ICD	inventory change documents
ICSANT	International Convention for the Suppression of Nuclear Acts of Terrorism
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
INFCIRC	Information Circular
IP	industrial packaging
IPPAS	International Physical Protection Advisory Service
ISL	in-situ leaching
ISR	in-situ recovery
ISPS Code	International Ship and Port Facility Security Code
ITDB	Incident and Tracking Database
JCPOA	Joint Comprehensive Plan of Action
JSCOT	Joint Standing Committee on Treaties
KAEC	Kazakhstan Atomic Energy Committee
KANUPP	Karachi Nuclear Power Plant
LSA	Low Specific Activity
MBA	Material Balance Area
MCA	Mineral Council of Australia
NCA	Nuclear Cooperation Agreement
NDA	Nuclear Decommissioning Authority
NEA	Nuclear Energy Agency
NMAS	Nuclear Material Accounting System
NMMSS	Nuclear Material Management and Safeguards System

NNWS	Non-Nuclear Weapons State
NPP	Nuclear power plant
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NRC	Nuclear Regulatory Commission (USA)
NSG	Nuclear Suppliers Group
NUMBAT	Nuclear Material Balances and Tracking
NWFZs	Nuclear Weapons Free Zones
NWS	Nuclear Weapons State
PAEC	Pakistani Atomic Energy Committee
PNNL	Pacific Northwest National Laboratory
PIV	Physical Inventory Verification
PP18	Policy Paper 18
PP21	Policy Paper 21
SOLAS	Convention for the Safety of Life at Sea
SSAC	State System for Accounting and Control
SWU	Separative Work Units
TEPCO	Tokyo Electric Power
TNRC	Tehran Nuclear Research Center
UAM	Uranium Asset Management (later Advanced Uranium Asset Management (AUAM))
UNDP	United Nations Development Programme
UOC	uranium ore concentrates
UPSAT	IAEA's Uranium Production Appraisal Team
UCF	Uranium Conversion Facility
UCIL	Uranium Corporation of India Ltd
WNA	World Nuclear Association
WNTI	World Nuclear Transport Institute

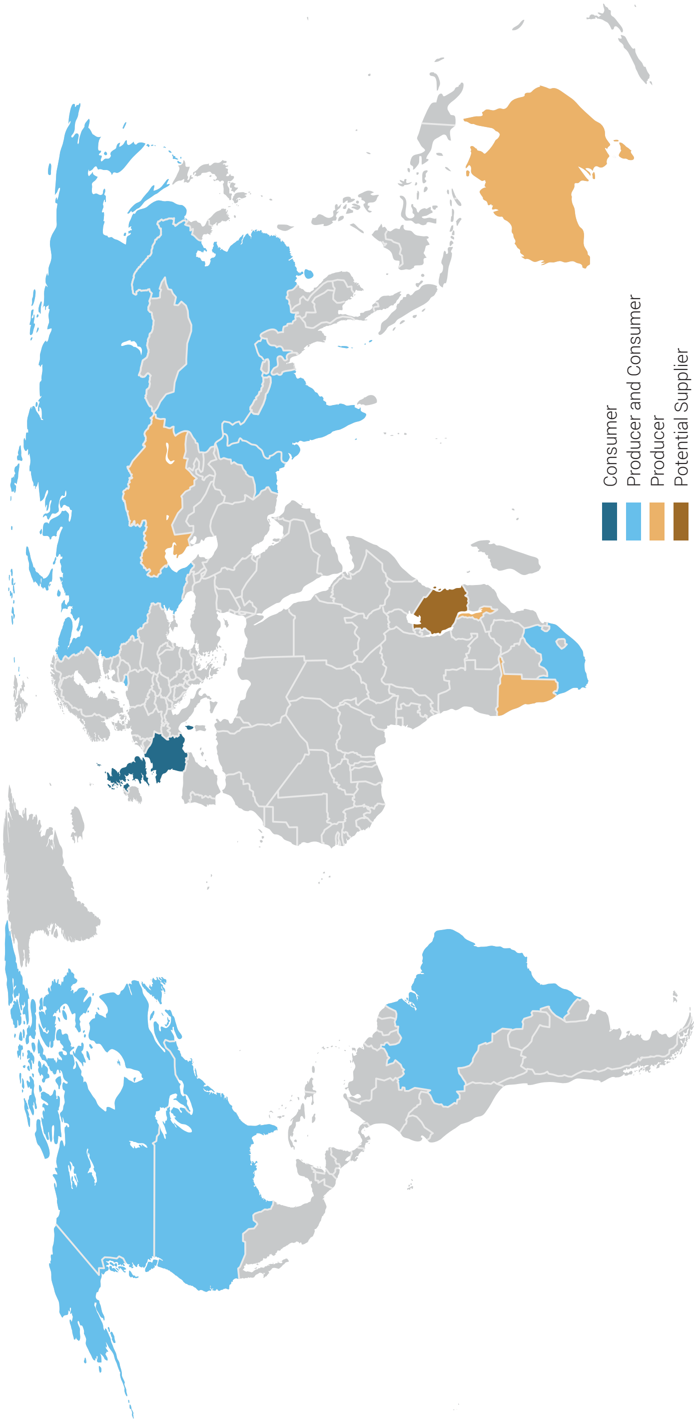
1. Introduction

Recent shifts in the market for natural uranium are introducing new challenges for physical protection, export controls, and the tracking of source materials such as processed uranium ore concentrates (UOC). Long-standing consumers such as Japan and Germany are shifting away from nuclear energy, while the ambitious nuclear energy programmes of China and Russia may soon increase global demand for natural uranium. Meanwhile, new suppliers (i.e. Malawi and potentially Tanzania and Greenland) and consumers (India and Iran) are entering the global market. These shifting geographies raise issues with regard to new supply routes, actors and costs; how to build national uranium regulatory systems from scratch; and the application of current export controls to countries outside the Nuclear Non-Proliferation Treaty (NPT). At the same time, technological advances are producing a purer product, prompting the International Atomic Energy Agency (IAEA) to re-clarify the nuclear material that is subject to its safeguards system to capture more material at the front-end of the nuclear fuel cycle. This evolving system of safeguards is creating new obligations for state regulatory authorities and industry, as well as increasing the IAEA's verification responsibilities.

The evolving structure of international nuclear treaties has also grown to include a range of security applications, with the 1987 Convention on the Physical Protection of Nuclear Materials (CPPNM) and its 2005 Amendment, UN Security Council Resolution 1540 of 2004, and the 2005 International Convention for the Suppression of Nuclear Acts of Terrorism (ICSANT). The provisions in these international legal instruments extend to the protection of UOC in international transport, as well as in domestic use, storage and transport. Coupled with a significant and corresponding evolution in uranium mining practices, first-time uranium suppliers are today entering a regulatory system that is markedly different than before, requiring the national development of safe, transparent and well-regulated operations in line with growing treaty obligations.

The *Governing Uranium* project is a global research effort studying how a changing global market is impacting on the governance of uranium production and trade. Led by the Danish Institute for International Studies (DIIS), up to twenty-five researchers from ten partner and supporting institutions have

Figure 1. *Governing Uranium* Countries Studied



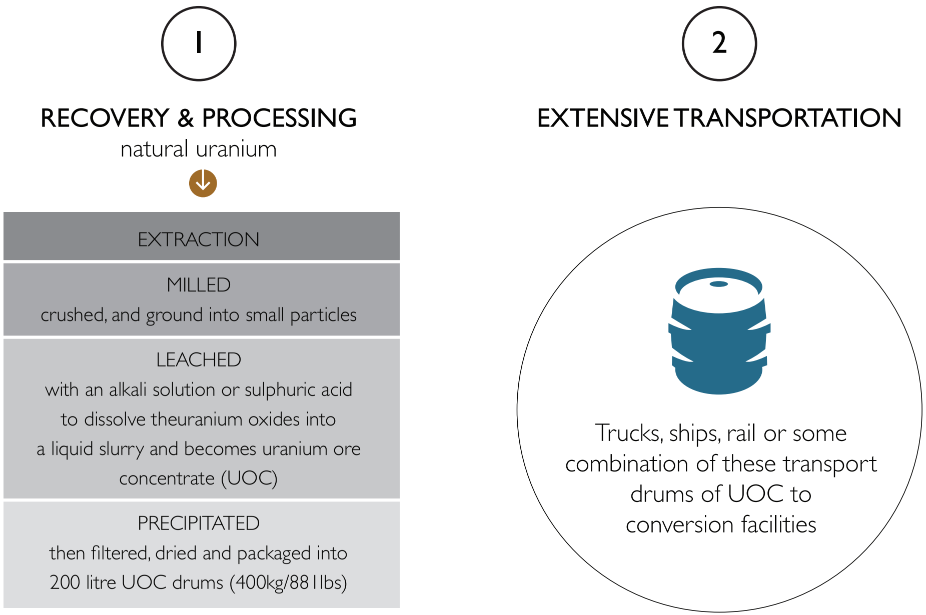
participated in the project. In total, fifteen uranium-producing and -consuming countries were studied, representing eighty-five per cent of global uranium production and seventy per cent of consumption.

The countries studied provide a cross-section of regulatory experiences from small producers (such as Brazil) via emerging suppliers (Malawi and Tanzania) to the largest producers (Kazakhstan, Canada and Australia). It includes states that are a party to the NPT and that possess nuclear weapons (China, France, Russia, United Kingdom and United States), non-NPT possessor states (India and Pakistan) and states that are members of nuclear weapons-free zones (NWFZs) such as Namibia and South Africa. Ten of the fifteen countries are members of the Nuclear Suppliers Group (NSG), twelve are parties to the Convention on the Suppression of Nuclear Acts of Terrorism (ICSANT), and one remains outside the Additional Protocol. The one treaty common to all is the 1987 Convention on the Physical Protection of Nuclear Material (CPPNM), with seven states still to ratify its 2005 Amendment. Regional safeguards agreements such as the Brazilian-Argentine

Table 1. International and Regional Membership of *Governing Uranium* Countries Studied

Membership / Country	*NPT*	*Additional Protocol*	*CPPNM (and 2005 amendment)*	*ICSANT*	*NSG*	*NWFZ*	*Regional Safe-guards*
Australia	√	√	√√	√	√	√	-
Brazil	√	-	√-	√	√	√	ABACC
Canada	√	√	√√	√	√	-	-
China	√	√	√√	√	√	-	-
France	√	√	√√	√	√	-	Euratom
India	-	√	√√	√	-	-	-
Kazakhstan	√	√	√√	√	√	√	-
Malawi	√	√	√-	√	-	√	-
Namibia	√	√	√-	-	-	√	-
Pakistan	-	-	√-	-	-	-	-
Russia	√	√	√√	√	√	-	-
South Africa	√	√	√-	√	√	√	-
Tanzania	√	√	√-	-	-	√	-
United Kingdom	√	√	√√	√	√	-	Euratom
United States	√	√	√-	-	√	-	-

Figure 2. Diagram of the Nuclear Fuel Cycle



Agency for Accounting and Control of Nuclear Materials (ABACC) and Euratom are also represented. Taken together, the list of countries offers variation in forms of governance at the international, multilateral, regional and national levels, as shown in Table 1.

The Nuclear Fuel Cycle

The front end of the nuclear fuel cycle generally includes all activities, from mining and milling to conversion and the loading of fuel elements into the core of a nuclear power plant. The focus of the *Governing Uranium* project is on the governance structure at the (very) front end of the fuel cycle: from uranium production and the processing and transport of UOC to the conversion facility. The rest of the fuel cycle is excluded, as the material changes form where full IAEA safeguards have historically been applied (i.e. the products of conversion, uranium dioxide, UO_2, or uranium hexafluoride, UF_6).

The most common compound of UOC is triuranium octoxide (U_3O_8), though some processes produce other compounds such as ammonium diuranate (ADU), uranium tetrafluoride (UF_4), uranium hexafluoride (UF_6), uranium dioxide (UO_2) and uranium trioxide (UO_3). U_3O_8 usually contains between 60 and 85 per cent uranium by weight. High purity UOC has a U_3O_8 content of over 99 per cent. Depending on its quality, the concentrate is sometimes further purified in a refinery and transported by road, rail and/or ships in metal containers to a conversion plant, anywhere from 100 km to 20,000 km away.

During conversion, the high purity required for nuclear fuel is achieved by dissolving UOC in nitric acid, and then filtering and treating the solution with chemical solvents. The resulting uranyl nitrate is more than 99.95 per cent pure. It is reconverted into uranium oxide, which in turn is converted into highly volatile UF_6 which is used in the enrichment process. For heavy water reactor fuel, enrichment is not required; instead UO_2 is produced from the uranyl nitrate and shipped directly to a fuel fabrication plant.

Methodology

All the researchers involved in the *Governing Uranium* project worked from the same set of questions to ensure comparability of variables across countries. Since many researchers found that no prior studies of uranium governance had been undertaken in their countries, generating a significant volume of relevant and specific data proved challenging. Terminology issues were also a source of significant complexity, starting with the very word 'uranium' itself, since isolating specific pieces of legislation related to natural uranium was not easy. In a number of countries, such as China, the commonly used term 'natural uranium' was left undefined throughout the relevant legislation, resulting in imprecise definitions as to the legal standing of uranium ore concentrates compared to the relatively clearer status of UF_6 and UO_2 as safeguarded materials.[1] As the country report on France underscores, where 'data exists, it is dispersed, requiring a huge work of consolidation.'[2]

There were additional challenges regarding the reporting of volumes, specifically of 'tonnes' and 'tons' of U_3O_8 and of 'tonnes uranium' (tU) equivalent in specific historical records, where short tons and metric tonnes are used almost interchangeably. When used in this report, they are reflective of the sources used in obtaining the information. Where the term 'uranium' is used in the report, it refers to uranium in the form of UOC unless stated otherwise.

All *Governing Uranium* researchers undertook extensive desk-based research utilising on-line resources, books and periodicals, fieldwork, digging through the respective national archives and conducting interviews with subject matter experts (including former and current officials and industry representatives). Their work has triangulated information and provided unique insights into an area that has otherwise remained relatively opaque. All partner researchers, as well as industry, Danish and Greenlandic officials, discussed the interim research results and draft papers in a closed seminar held on 23-24 September 2013 at DIIS in Copenhagen, followed by a public 'Governing Uranium' seminar on 25 September 2013.[3] Many of the researchers also held their own closed seminars with officials and industry representatives in their respective capitals to provide input for or to review their draft reports. DIIS participated in some of these seminars. The project began on 1 January 2013 and ends on 30 October 2015.

[1] Such as in China, where there is uncertainty over whether UOC actually qualifies as 'uranium ore' or whether UOC should be considered a source material. As Tamara Patton Schell notes, this represents a serious gap in Chinese legislation. See Tamara Patton Schell, *Governing Uranium in China*, DIIS Report 2014:03, p. 6.

[2] Bruno Tertrais and Cécile Padova, *Governing Uranium in France*, DIIS Report 2014:17, p. 5.

[3] Governing Uranium Public DIIS Seminar, 25 September 2013: http://en.diis.dk/home/news/2013/governing+uranium+public+seminar+online.

Policy Relevance

The *Governing Uranium* project provides a mapping of an evolving system of treaties, guidelines, and regional and national obligations at a time when the market is shifting both structurally and geopolitically. This regulatory snapshot is particularly relevant as more front-end materials fall under the IAEA safeguards system, placing new obligations on state regulatory authorities and industry and facility operators, as well as new verification responsibilities on the IAEA. On security, a series of Nuclear Security Summits since 2010 have raised awareness of the need to apply nuclear security across the entire nuclear fuel cycle, while ratification and implementation of the CPPNM's 2005 Amendment is adding another layer of regulatory oversight. Geopolitically, India's recent re-entry into the global nuclear market has created an 'India-specific' structure which is challenging the system of export controls and safeguards that took three decades to build up. Lastly, as the nuclear fuel cycle becomes increasingly global, with utility companies and countries diversifying their procurement plans, and as more uranium is being recovered from unconventional sources imported from abroad, states could run into unwanted barriers in the international market unless they pay attention to front-end regulatory issues. This means that, although the three rules of real estate apply to uranium (location, location, location), the uranium market is still global, while export controls and nuclear security are still local (that is, national). The expansion of civilian nuclear fuel cycles to new centres of production and consumption thus calls for increased harmonisation of regulations across states.

The report begins with a look at the uranium industry (Chapter 2), followed by descriptions of the evolving application of IAEA safeguards (Chapter 3) and the international nuclear security structure (Chapter 4) as it applies to front-end governance. Chapter 5 analyses best practices in tracking and inventory controls to ensure that safeguards and security obligations are met efficiently and effectively. Each chapter provides recommendations for addressing governance gaps at the international and national levels as the industry undergoes legal and structural reforms. It attempts to assist long-time suppliers in updating governance approaches and newcomers in developing nationally appropriate regulatory systems from scratch based on global best practices.

2. The Uranium Industry

Uranium is a common element, found in the Earth's crust in concentrations upwards of 20 per cent uranium or 200,000 parts per million (ppm) in very high-grade ore such as that found in Canada's Athabasca Basin, to 0.01% (100 ppmU) in very low grade ore such as that found in Namibia and 0.003 ppmU found in seawater.

There are four primary techniques for uranium recovery: open pit mining, underground mining, in situ recovery and heap leaching. Open pit mining is used to recover uranium located near the earth's surface. Explosives are used to break up the rock, which is loaded on to large dump trucks and then to crushers and separators to prepare the ore for leaching. Uranium mines such as the Ranger mine in Australia, the Rössing mine in Namibia and the Arlit mine in Niger are open pit. When uranium is located at depths that make the open pit method uneconomical, extraction is done by digging a shaft underground into the uranium deposit. Horizontal tunnels are then excavated to access the ore, which is broken up by explosives or boring machines. Mechanical conveyors then hoist the broken rock to the surface. Russia's Priargunsky mine and Canada's MacArthur River and Cigar Lake mines are underground. At Cigar Lake, where concentration levels are higher than average, the rock is crushed to a finer consistency and mixed with water to produce a slurry that is pumped to the surface and transferred to a mill for further processing. Given its high concentrations, Canada is the only producer that has to 'water down' its rock.

Table 2. Concentration of Uranium Ore

Ore	*ppmU*
Very high-grade ore (Canada) – 20%	200,000
High-grade ore – 2%	20,000
Low-grade ore – 0.1%	1,000
Very low-grade ore (Namibia) – 0.01%	100
Granite	3-5
Sedimentary rock	2-3
Earth's continental crust (average)	2.8
Seawater	0.003

Source: World Nuclear Association: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/

Heap leaching uses a series of chemical reactions that absorbs specific minerals and then re-separates them after extraction. After the ore has been removed and crushed, it is placed into heaps on a protective liner which is sprayed with a leaching solution (alkali solution or sulphuric acid) to separate the uranium from the ore. The Caetité uranium mine in Brazil is open-pit and uses the heap leaching technique as does AREVA's Somair mine in Niger. In situ leaching (ISL), also known as in situ recovery (ISR), is similar except that liners are not used; instead the leaching solution is pumped through a network of piping into the deposit, dissolves the uranium and pulls a pregnant solution up to the surface. As such, ISL extracts uranium without excavating it. Mines in Kazakhstan and United States are predominantly ISL.

The sequential stages of mining, milling, extraction, concentration and purification will vary from facility to facility. Some facilities produce slurry at the mine that is shipped to a concentration plant. Other facilities have every stage of the process through purification at a single plant. In situ leach facilities do not have the milling stage. The percentage of world production from underground mines was 55 per cent in 1990, shrinking to 33 per cent in 1999. New Canadian mines increased the percentage from 2000, and with Olympic Dam, this figure has now reached 48 per cent (without Olympic Dam it is 42 per cent). ISL mining has also been steadily increasing its total share, mainly due to Kazakhstan mines, and for the first time in 2014 it represented more than half of production. In 2014, the breakdown of production was as follows:

Table 3. World Production of Uranium by Method 2014

Method	*tonnes U*	%
Underground & open pit (except Olympic Dam)*	23,679	42%
In situ leach (ISL)	28,467	51%
By-product*	4,107	7%

* Considering Olympic Dam as by-product rather than in underground category

Source: WNA webpage: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Mining-of-Uranium/World-Uranium-Mining-Production/

Uranium recovered as a primary product, a co-product or an important by-product through one of the mining techniques counts as conventional resources. Unconventional resources are resources from which uranium is recoverable as a minor by-product of, for example, the production of coal and phosphates. According to the World Nuclear Association (WNA), approximately 20,000 tU have been recovered from phosphates to date, with an additional 9-22 million tU that could be recovered from phosphate rock or phosphorite, three times more than identified conventional sources.[4] In the United States, eight plants for the recovery of uranium from phosphoric acid have been built and operated since the 1970s (six in Florida and two in Louisiana). Plants have also been built in Canada, Spain, Belgium (for Moroccan phosphate), Israel and Taiwan. Brazil is planning a new plant with uranium as a by-product of phosphate from 0.08%U ore. [5] Morocco, however, has the largest known resources of uranium in 50 billion tonnes of phosphate rock, or 85 per cent of world reserves containing 6.9 million tU. [6] While it is economically unrealistic to extract uranium from phosphates until prices increase significantly, it has been considered a route for a state interested in developing a clandestine programme, albeit with varying success, as in the case of Iraq.[7]

Cameco and an Australian company, Uranium Equities, are working on the PhosEnergy process to remove uranium from phosphate streams during the fertiliser production process. The construction of a portable production process in the United States was commissioned in May 2012 and completed four ten-day tests at two different fertiliser plants. Positive results have been reported, with uranium recovery at more than 90 per cent.[8]

Research into the extraction of uranium from seawater was conducted in Germany, Italy, Japan, the United Kingdom and the United States from the 1950s to the 1980s and again by Japan in the 1990s. In 2012, researchers at the US Department of Energy's Oak Ridge National Laboratory and the Pacific Northwest National Laboratory tested improvements to Japanese technology, reducing overall production costs. The cost, however, is still high, at US$660/kgU. While uranium by extraction from seawater is attractive, given almost inexhaustible resources (over 4 billion tU), low concentrations of 0.003-0.004 ppmU makes developing cost-effective methods of extraction challenging and seawater extraction a far-off promise.[9]

[4] 'Uranium from Phosphates,' World Nuclear Association: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Uranium-from-Phosphates/. Accessed 29 June 2015.

[5] Ibid.

[6] 'World's largest exporter of phosphate undergoes major transformation,' *MIT Sloan Management*, 14 February 2014. See also: 'Phosphate: Morocco's White Gold,' *Bloomberg Business*, 4 November 2010.

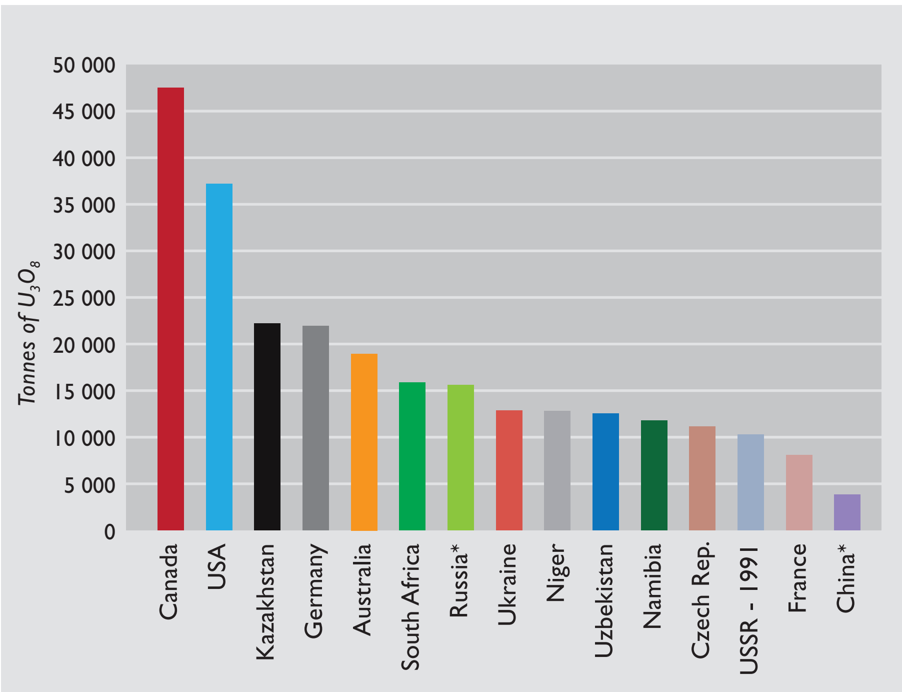
[7] See reports of the Iraq Nuclear Verification Office (INVO), specifically on the Al Qaim uranium recovery facility: 'Fourth consolidated report of the Director General of the International Atomic Energy Agency under paragraph 16 of Security Council resolution 1051 (1996),' S/1997/779, p. 27.

[8] OECD/IAEA, 'Uranium 2014: Resources. Production and Demand', p. 36.

[9] Ibid., p. 37.

Uranium is also unique among energy minerals in that it can be recovered from other 'secondary' sources such as waste tailings and military and commercial stockpiles of natural, low-enriched and highly enriched uranium (HEU), depleted uranium or 'tails' with lower U^{235} concentration,[10] and reprocessed uranium obtained by recycling spent nuclear fuel. A 2014 joint report by the OECD's Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), also known as the 'Red Book,' notes that, while information on secondary sources is incomplete, their availability declined somewhat after 2013, when the agreement between the United States and Russia to blend down HEU ended. Limited available information also indicates that there remains a significant amount of previously mined uranium (including material held by the military), which may be brought to market at some time in the future. The report also notes that enrichment

Figure 3. Total World Production by Country 1945-2013



*Estimated by Secretariat of OECD/WNA.

Source: OECD NEA & IAEA, *Uranium 2014: Resources, Production and Demand* ('Red Book') and WNA *Global Nuclear Fuel Market Report* data.

[10] A by-product of the enrichment of natural uranium that can also be used after additional enrichment.

providers are well-positioned to reduce tails assays below contractual requirements and create additional uranium supply, given that the transition from gas diffusion to centrifuge enrichment has now been successfully completed, and that capacity is now in excess of requirements following the Fukushima Daiichi accident. Moreover, if a commercially viable means of re-enriching depleted uranium (DU) is developed, along with the potential for laser enrichment of DU, a considerable source of secondary supply could become available.[11]

In total, world production of conventional resources of uranium from 1945 to 2013 is estimated at 2,769,107 tU across thirty countries, with Canada (474,820 tU) topping the list, followed by the United States (371,941 tU), Kazakhstan (221,864 tU), Germany (219,652 tU) and Australia (189,589 tU).[12] The top fifteen all-time producers are charted in Figure 3.

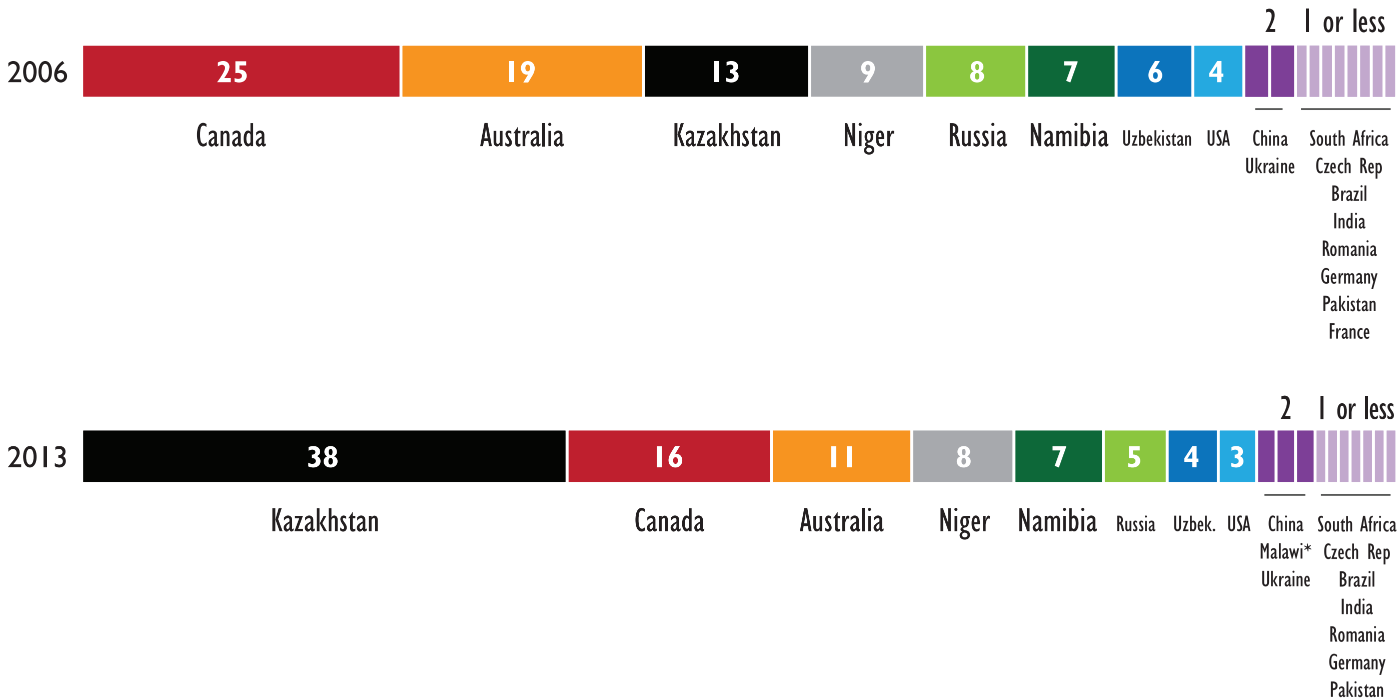
2.1 Shifting Geographies

Presently the uranium market is shifting, as new suppliers and consumers are entering the global market. Long-standing consumers such as Japan and Germany are turning away from nuclear energy, while the ambitious nuclear energy programmes of China, Russia and India may soon increase global demand for natural uranium. New suppliers such as Malawi and emerging suppliers such as Tanzania and Greenland are entering the market, while Kazakhstan continues to increase its production year by year, surpassing Canada and Australia to becoming the world's largest supplier in 2009. Today, Kazakhstan produces over 20,000 tonnes of uranium (tU), or 38 per cent of total global production in 2013, which is more than the production of Canada and Australia (the second and third largest producers) combined. By 2017, it aims to increase annual production further to 37,000 tU. The four African states that currently produce uranium – Malawi, Namibia, Niger and South Africa – together produced 10,700 tonnes of uranium by 2012, or 18 per cent of world output. Namibia accounted for 8.0 per cent of global production, Niger for 7.7 per cent, Malawi for 1.9 per cent and South Africa for 0.8 per cent. Figure 4 charts the percentage of the world's uranium production from mines since 2006.

[11] OECD/IAEA, 'Uranium 2014: Resources. Production and Demand', pp. 14-15.

[12] The remaining list includes South Africa (158,944 tU), Russia (155,853), Ukraine (128,846), Niger (127,950), Uzbekistan (125,191), Namibia (117,646), Czech Republic (111,621), USSR (102,886 to 1991), France (80,963), China (38,249), Democratic Republic of Congo (25,600), Gabon (25,403), Hungary (21,059), Romania (18,819), Bulgaria (16,364), India (10,028), Spain (5,028), Brazil (4,123), Malawi (3,848), Portugal (3,720), Argentina (2,582), Pakistan (1,390), Madagascar (785), Belgium (686) and Poland (650). Source: OECD NEA & IAEA, *Uranium 2014: Resources, Production and demand* ('Red Book') and WNA, *Global Nuclear Fuel Market Report* data.

Figure 4. Percentage of World's Uranium Production from Mines, 2006-2013



* Country did not produce uranium from mines in 2006.

Source: *'Governing Uranium - Production'*, CSIS and DIIS: http://uranium.csis.org/production/

2.2 The Global Demand for Uranium

The demand for uranium depends largely on installed and operating reactors, regardless of economic fluctuations. The demand for uranium is therefore much more predictable than with other mineral commodities.[13] Uranium is typically mined outside the countries that use it. About two-thirds of world production in 2014 came from Kazakhstan, Canada and Australia, while more than half of the world's commercial reactors are in the United States, France and Japan. The United States, with over 100 operating nuclear power reactors, continues to have a major appetite for enriched uranium (about 58 million pounds of UO_3 equivalent per year). Since 2005 many of the main markets for nuclear power projects have been expanding primarily in Asia and Eastern Europe, including China, India, South Korea, Russia, Ukraine and the United Arab Emirates.[14]

According to the WNA, a total of 435 commercial reactors were connected to the grid in 2014, with a combined capacity over 370 GWe, requiring annually approximately 78,000 tU_3O_8 (containing 66,000 tU) from mines, or the equivalent from stockpiles or secondary sources.[15] The 2014 NEA-IAEA Red Book states that in 2012 world uranium production reached 58,816 tU, providing about 95 per cent of world reactor requirements.[16] While production is growing, reactors are also being operated more efficiently, with lower amounts of uranium required given higher capacity factors and reactor power levels. From 1970 to 1990, these improvements led to a 25 per cent reduction in uranium demand per KWh output in Europe, which continues to this day.[17] The WNA notes that from 1980 to 2008 the electricity generated by nuclear power increased 3.6-fold, while uranium use increased by a factor of only 2.5.[18]

Looking ahead to the next two decades, installed capacity is expected to grow as planned reactors come online. The WNA estimates a 36 per cent increase in reactor capacity over 2013-2023, accompanied by a 31 per cent increase in uranium

[13] World Nuclear Association, 'Uranium Markets,': http://www.world-nuclear.org/info/nuclear-fuel-cycle/uranium-resources/uranium-markets/. Accessed 24 May 2015.

[14] Ian Anthony and Lina Grip, 'Africa and the Global Market in Natural Uranium: From Proliferation Risk to Non-proliferation Opportunity,' SIPRI Policy Paper No. 39, November 2013, p. 17.

[15] World Nuclear Association, 'Uranium Markets,': http://www.world-nuclear.org/info/nuclear-fuel-cycle/uranium-resources/uranium-markets/. Accessed 24 May 2015.

[16] OECD/IAEA, 'Uranium 2014: Resources. Production and Demand', Executive Summary, p. 8.

[17] World Nuclear Association, 'Uranium Markets,': http://www.world-nuclear.org/info/nuclear-fuel-cycle/uranium-resources/uranium-markets/. Accessed 24 May 2015.

[18] Ibid.

demand.[19] Red Book projections to 2035 suggest a wider range, with world nuclear capacity growing by between 400 GWe net (7% growth from 2013) in the low demand case and 680 GWe (increase of about 82%) in the high demand case.[20] Annual demand for uranium is thus expected to rise by between 72,000 tU and 121,100 tU respectively.[21] These projections are dependent upon the rate at which new power plants are built, old ones retired and lifetime extensions granted. The situation in Japan provides the greatest uncertainty due to the 2011 Fukushima Daiichi nuclear accident. Since the crisis none of Japan's fifty reactors (43 of which are operable) have restarted and Tokyo Electric Power (TEPCO) has not consumed any uranium. A key milestone was reached in July 2015 when fuel loading at Kyushu Electric Power Company's Sendai 1 began, with restart planned for mid-August and full power operations by September.[22] As of March 2015, TEPCO had a stockpile of 17,570 tU, which is anticipated to reach 19,317tU by the end of the 2015 fiscal year due to supply contracts.[23]

Stocks are also growing in China. In anticipation of uranium demand jumping from 4,000 in 2013 to 10,000–20,000 tU in 2020, Beijing has been importing more uranium than it currently consumes. The *China Daily* reported that China imported 17,135 tU in 2012 and 16,126 tU in 2011.[24] In July 2015, India announced that it would create a strategic uranium reserve between 5,000 – 15,000 metric tonnes. [25] Meanwhile, Russia has been burning through its uranium stocks, which stood at 200,000 tU in 1991 and 47,000 tU in 2010. While still a large stockpile, Russia has stopped selling uranium from its domestic reserves to foreign countries, using 3,000 tU from its reserves each year domestically. Some estimates suggest that routine supplies from the stockpile will be exhausted by 2020 to a bare minimum for emergency supply.[26] According to the WNA, uranium stockpiled by utilities in Europe and USA at the end of 2013 was estimated at more than 90,000 tU.[27]

[19] Ibid.

[20] OECD/IAEA, 'Uranium 2014: Resources. Production and Demand', p. 100.

[21] Ibid., p. 101.

[22] Nuclear Energy Institute, 'Japan Nuclear Update,' 9 July 2015: http://www.nei.org/News-Media/News/Japan-Nuclear-Update. Accessed 10 July 2015.

[23] 'TEPCO's Uranium Stockpile Sale Likely a "One-off" Move,' *Uranium Investing News,* 19 May 2015.

[24] Q. Ding and L. Yiyu, 'Nation Plans to Import More Uranium,' *China Daily*, 2012.

[25] 'India to create strategic uranium reserve,' *Mining.com*, 19 July 2015.

[26] Anton Khlopkov and Valeriya Chekina, *Governing Uranium in Russia,* DIIS Report 2014:19, p. 19.

[27] Uranium Markets, World Nuclear Association: http://www.world-nuclear.org/info/nuclear-fuel-cycle/uranium-resources/uranium-markets/. Accessed 24 May 2015.

2.3 Historical Production

The Uranium Rush

The global market for uranium was small in the early years. Prior to 1940, total global production of U_3O_8 has been estimated at 7,500 tons.[28] At the time, radium was the target, used for its bright yellow pigment in colouring ceramics and its gamma rays for the treatment of cancer. Uranium was considered an annoying and hefty waste product, taking as much as one short ton of uraninite (pitchblende) to yield one-seventh of a gram of radium. But the rewards were financial: by 1911 radium had reached a price of approximately £13,000 per gram.[29]

By 1939, top government officials in Europe, Russia and United States were beginning to recognise the strategic importance of uranium. In 1939, France's Centre National de la Recherche Scientifique (CNRS) received eight tons of uranium oxide (U_3O_8) from the Union Miniére du Haut Katanga operating in the Belgian Congo and bought 400 kg (880 lbs) of uranium metal from the United States. As the German army advanced on France in June 1940, part of that uranium was sent to French Morocco and hidden in a mine.[30] In the United States, the first wartime order was sent to Canada in the spring of 1941 for preliminary experiments, followed by another in 1942, which Dr Enrico Fermi used to create the world's first self-sustaining nuclear chain reaction at the University of Chicago.[31] In 1942, Russia's Resolution 'On Uranium Mining' ordered the start of uranium production in Tajikistan, with the focus shifting in the second half of the 1940s to deposits in Eastern Europe.[32] The 'uranium rush' had begun.

During these early years, uranium was considered a scarce resource. In June 1944, the United Kingdom and the United States established the Combined Development Trust (CDT, later the Combined Development Agency or CDA) to 'secure control of uranium and thorium' within their territories and in third countries. In the seven years following the war, more than 85 per cent of all U.S. uranium came from the Congolese Shinkolobwe mine.[33] Altogether, almost half of

[28] Sharon Squassoni et al., *Governing Uranium in the United States*, CSIS Report, March 2014, p. 8.

[29] 'Early Workings', Radium Hill Historical Association: http://radiumhill.org/early.htm. Accessed 10 September 2013.

[30] Bruno Tertrais and Padova, *Governing Uranium in France,* DIIS Report 2014:17, p. 8.

[31] Sharon Squassoni et al., *Governing Uranium in the United States*, CSIS Report, March 2014, p. 8.

[32] Anton Khlopkov and Valeriya Chekina, *Governing Uranium in Russia,* DIIS Report 2014:19, p. 18.

[33] Sharon Squasson et al., *Governing Uranium in the United States*, CSIS Report, March 2014, p. 8.

the uranium used in the U.S. nuclear weapons complex was initially imported from other countries.[34] As noted by the report on *Governing Uranium in the United Kingdom*, the overriding focus for the CDT was 'acquiring as much uranium as possible to make as many atomic bombs as possible'. So much was this the case that the UK Department of Atomic Energy commissioned a legal review in 1947 to check whether uranium acquired from the Belgian Congo through the CDT could be used for civilian energy purposes.[35]

Meanwhile, Moscow signed its first international agreement on cooperation in uranium exploration in 1945 with Bulgaria. Similar deals soon followed with Czechoslovakia, Hungary, Poland and Romania.[36] In 1947, the Soviets set up the Wismuth (Bismuth) uranium mining company in East Germany.[37] From 1946 to 1950 Wismuth delivered 2,478 tonnes of uranium to the Soviet Union, whereas the country's own uranium mines produced only 1,056 tonnes between them. The second-biggest supplier of uranium to the Soviet Union at the time was Czechoslovakia.[38] Meanwhile, the French repatriated its stockpile from Morocco and benefitted from several tons of sodium uranate (the equivalent of three tons of UO_2) of Belgian origin found at Liberation in a train wagon at Le Havre. In 1948, the Commissariat à l'Energie Atomique (CEA) launched a major prospection effort across the country, with promising discoveries at La Crouzille (Limousin) consisting of ores with a concentration of 2-10 per cent. In 1949 production amounted to 75 tonnes, and by 1953 the CEA had turned to chemical (as opposed to physical) treatment of the ore. Two years later private mining was allowed, and by 1958 France had produced a total of 1,823 tonnes of uranium on its territory.[39]

By the mid-1950s, the CDA's uranium purchases were being accompanied by discoveries of uranium in the United States. By 1959 the US Atomic Energy Commission (AEC) had more than enough yellowcake for the U.S. nuclear weapons programme and began phasing out its foreign uranium purchases, halting them altogether in 1966. An official embargo prohibiting U.S. utilities from using

[34] Specifically Canada, the former Belgian Congo, as a by-product of gold mining in South Africa, and early uranium recovery in Australia. Squassoni et al. 2014, *Governing Uranium in the United States*, CSIS Report, March 2014, p. 8.

[35] Berkermeier et al., *Governing Uranium in the United Kingdom*, DIIS Report 2013:02, pp. 4-5.

[36] I.A Andryshin., A.K. Chernyshev, Y.A. Yudin, *Taming the Atom: Pages of History of Soviet Nuclear Weapons and Nuclear Infrastructure*, Sarov, 2003, p. 294.

[37] It later became a joint Soviet-East Germany stock company.

[38] Anton Khlopkov and Valeriya Chekina, *Governing Uranium in Russia,* DIIS Report 2014:19, p. 19.

[39] Bruno Tertrais and Cécile Padova, *Governing Uranium in France,* DIIS Report 2014:17, p. 9.

foreign-origin uranium effectively shut the U.S. out of the global market it had created and led to an immediate problem of oversupply with little demand. In France, this led to production being limited in the 1960s to 1,200-1,600 tons per year, and the figure never exceeded 1,400 tons until 1972.[40] In Australia, reserves were depleted and contracts filled. By 1964 production was essentially stalled except at Rum Jungle, which went on producing until 1971.[41] In Canada, mines were operating at one-third of capacity.[42] By 1971, 80,000 tU of were being held as stockpiles by the governments of Australia, Canada, France, South Africa, United Kingdom and United States – four times as much as annual production in the West at the time.[43] A further 100,000 tons of non-US uranium was estimated to be made available for sale for the six-year period to 1977, with demand at perhaps only 26,000 tons.[44]

An unintended consequence of the US policy was the rise of a clandestine international uranium cartel to keep uranium prices buoyant. Established in 1976, the cartel involved governments and mining companies from Canada, Australia, France, Gabon and South Africa, as well as an international mining firm with headquarters in England. Their objective was to control the supply and increase the price of non-American uranium. As OPEC, another and greater cartel, decided it was not getting enough for its oil, the price of oil (and thereafter the price of all energy-related commodities) soared. The uranium cartel's ambitions were then overshadowed by the unprecedented prices being offered on the open market, leading to its collapse before it ever really got going.[45]

However, in recognition that domestic mines and mills would be unable to fulfil U.S. demands indefinitely, the AEC's embargo began to be phased out. In 1974, the AEC contracted for the purchase of 33,000 tons of foreign uranium, and by mid-1977, 14 per cent of their purchasing commitments were coming from non-American sources.[46] After reaching a peak in 1979, when the United States was the largest producer of yellowcake, with an estimated 45 per cent of global production, domestic production started to decline significantly. U.S. operators

[40] Ibid., p. 10.
[41] Cindy Vestergaard, *Governing Uranium in Australia*, DIIS Report, forthcoming 2015.
[42] Earle Gray, *The Great Uranium Cartel*, Toronto, McClelland and Steward, 1982, p. 97.
[43] Ibid., p. 95.
[44] Ibid., p. 122.
[45] Harry Swain, 'Why Canada Supported a Uranium Cartel,' *The Globe and Mail*, 12 July 2011.
[46] Earle Gray, *The Great Uranium Cartel*, Toronto, McClelland and Steward, 1982, p. 157.

have bought much more foreign uranium since the end of the Cold War, up from 30.6 million pounds in 1993 to 47.7 million in 2012. While the U.S.–Russian HEU downblending agreement played a large role in this, new uranium suppliers such as Namibia, Niger and Malawi, as well as sellers in the former Soviet Union (e.g. Kazakhstan and Uzbekistan), have also become suppliers to the United States. Today, the United States ranks eighth in global yellowcake production.[47]

In the meantime, other producers had emerged. Pakistan established the Pakistan Atomic Energy Committee (PAEC) and set up a Nuclear Minerals Division at the Atomic Energy Centre at Lahore in 1961. Initial surveys at Siwaliks of the Suleiman Range (Dera Ghazi Khan) considered their 'uranium favourable.'[48] In 1969, the IAEA Minerals Advisor visited the Baghalchur site and offered technical assistance in exploring for uranium, leading to a joint IAEA/UNDP Technical Assistance Project in Dera Ghazi Khan in 1971.[49] China also began prospecting for uranium domestically in 1955, initially with the aid of the Soviet Union. The development of the first uranium mines and mills occurred in 1958, with the Chenzhou and Dabu mines and the Henyang mill (all in Hunan Province) commencing operations in 1962 and 1963 respectively.[50] In India, the Uranium Corporation of India Ltd (UCIL) was established in 1967 to mine and process uranium in India. The Jaduguda uranium mine began operations in 1967.[51]

The Second Uranium Wave

The next wave of global uranium exploration took off from 1974 to 1983, leading to major discoveries. In Australia, where the second wave had begun the decade before, the majority of its ninety uranium mines[52] were identified, including Narbalek and Koongarra (1970), Jabiluka (1971) and the Ranger mine in 1969. The latter had reserves of more than 100,000 tonnes, making it one of the largest uranium

[47] Sharon Squassoni et al., *Governing Uranium in the United States*, CSIS Report, March 2014, p. 54.

[48] Maria Sultan et al., *Governing Uranium in Pakistan*, DIIS Report 2015:08, p. 15.

[49] The IAEA provided drilling rigs, borehole loggers, scintillometers, vehicles, communication equipment, assortments of spares and, finally, experts in exploration and drilling. Exploration continued for the next six years with IAEA technical assistance. See Maria Sultan et al., *Governing Uranium in Pakistan*, DIIS Report 2015:08, p. 18.

[50] It is therefore possible that the first processed military uranium was of Chinese domestic origin as opposed to Soviet-supplied. See Tamara Patton Schell, *Governing Uranium in China*, DIIS Report 2014:03, p. 19.

[51] Rajiv Nayan, *Governing Uranium in India*, DIIS Report 2015:02, p. 18.

[52] The WNA notes that 60 deposits were identified from the 1950s through to the late 1970s. See: www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Australia/. (Accessed 15 May 2015). Geosciences Australia however notes that of the 90 uranium deposits in Australia, the majority were discovered between 1969 and 1975. See: 'Uranium', Geosciences Australia, www.ga.gov.au/scientific-topics/minerals/mineral-resources/aimr/uranium. (Accessed 5 March 2014).

deposits ever discovered at the time. In 1975, the Olympic Dam copper-uranium-gold-silver deposit, one of the world's largest known accumulations of metals, had also been identified, containing more than 1,000,000tU as a by-product. This was followed by Cigar Lake in 1981, the world's highest grade uranium deposit (average of 17.8% U_3O_8)[53] until the discovery of McArthur River in 1988 took the top spot with proven reserves of 23% U_3O_8.[54] Both are located in northern Saskatchewan, Canada. Others, such as the Trekkopje mine in Namibia and Kayelekera in Malawi, were also discovered.

Across countries, exploration expenditure and drilling, as well as production capacity, expanded dramatically in 1974 and peaked in the early 1980s before declining back to zero in the early 2000s.[55] Starting in 1975, for example, France imported more uranium from abroad than it produced on its territory and had begun to sell significant quantities of natural uranium to western countries such as Belgium, Japan and Sweden. Starting from 200 tons in 1972, exports reached 3,050 tU in 1978.[56] In 1989, domestic production peaked at 3,720 tU. This allowed France to meet half the demand of its reactors.[57] Domestic mining started to decrease in 1989, as foreign mining became the most cost-effective. In 1992 domestic production was 2,149 tU, France then being the world's fifth largest producer. 2001 was the last year of significant uranium production in France (195 tons). After the closing of the last mine at Jouac-le-Bernardin (Haute-Vienne) in May 2001, production rapidly fell to 18-20 tons in 2002 and 2-6 tons in 2011 (from remediation activities at the Herault mines).[58]

Production peaked in East Germany in 1967 at 7,000 tonnes, while in the Soviet Union the majority of production in Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) and Ukraine continued to increase year on year. According to Khlopkov and Chekina, Soviet production peaked at 16,000-16,500tU in 1985-1986.[59] Global uranium production peaked at 68,000 tonnes

53 'Cigar Lake,' Cameco Corporation: http://www.cameco.com/businesses/uranium-operations/canada/cigar-lake. (Accessed 25 May 2015).

54 Cameco, *McArthur River Operation, Northern Saskatchewan, Canada, Technical Report*, November 2012, p. 7.

55 OECD/IAEA, *Forty Years of Uranium Demand, Production and Perspectives*, op. cit., p. 46.

56 Bruno Tertrais and Cécile Padova, *Governing Uranium in France,* DIIS Report 2014:17, p. 11.

57 Ibid., p. 15.

58 Peter Diehl, *Uranium Mining in Europe: The Impact on Man and the Environment*, WISE, 1995 (electronic version).

59 Anton Khlopkov and Valeriya Chekina, *Governing Uranium in Russia,* DIIS Report 2014:19, p. 20.

in 1982.[60] Germany stopped production at the Wismut uranium mine after the reunification of the country in 1990. The mine produced a total of 216,000 tU over its lifetime, making it the world's largest uranium mine of all time. Wismut GmbH was created in 1991, with the Federal Republic of Germany as the sole owner. Its purpose has been to decommission the world's largest producing mine and its processing facilities and to rehabilitate the sites. Germany has committed 6.2 billion EUR to the remediation, making it also the single biggest mining rehabilitation effort in the world.[61]

A number of mines that were opened up during the 1970s and the 1980s are still producing today. Ore was first mined in 1968 at Russia's Priargunsky Mining and Chemical Combine built in the Chita Region (now the Trans-Baikal Territory). Production peaked at 5,400 tonnes in 1985, when the facility was one of the largest in the world. The company has produced about 140,000 tU over its 45-year lifetime and is currently the world's oldest (and largest) operational uranium mining facility.[62] Mining at Niger's Arlit (Somair) mine began in 1970, producing more than 58,400 tU by the end of the 2013.[63] Coupled with its sister underground mine, Cominak, which began production in 1978, the two have produced more than 124,000tU.[64] Namibia's Rössing mine, opened in 1976, had produced a total of 127,405 tU U_3O_8 by the end of 2014.[65]

As for Australia's oldest producing mine, Ranger concluded all open-pit mining in December 2012 after thirty-two years and a total production of 110,000 tU_3O_8.[66] In 2013, Energy Resources Australia (ERA) produced 2,960 tonnes of uranium oxide from Ranger's stockpiled ore[67] and 988tU by the end of 2014.[68] The top five all-time mines with the largest total production figures are : 1) Wismuth;

[60] Cherkasenko Andrey, *Investing in Uranium*, Moscow, Alpina Publisher, 2013, p. 72.

[61] Michael Paul, Division Head Engineering, Development and Monitoring, WISMUT GmbH, 'The WISMUT Experience in Remediation of Uranium Mining and Milling Legacies,' presentation at the IAEA Technical Meeting, Swakopmund, Namibia, 1-5 October 2007.

[62] Anton Khlopkov and Valeriya Chekina, *Governing Uranium in Russia,* DIIS Report 2014:19, p. 21.

[63] 'Somair Open Pit Mine Operations,' AREVA: http://www.areva.com/EN/operations-675/somair-seeking-greater-competitiveness.html. Accessed 26 May 2015.

[64] 'Cominak, Operator of the Largest Underground Uranium Mine,' AREVA: http://www.areva.com/EN/operations-602/cominak-operator-of-the-largest-underground-uranium-mine.html. Accessed 26 May 2015.

[65] Rio Tinto, 'Rössing Uranium': http://www.rossing.com/riotinto.htm. Accessed 26 May 2015.

[66] Energy Resources Australia, 'Operations,' Accessed 25 July 2014: http://www.energyres.com.au/whatwedo/2326.asp

[67] Energy Resources Australia, 'History,': http://www.energyres.com.au/whoweare/2312.asp. Accessed 25 July 2014.

[68] 'Australia and Kazakhstan Report Uranium Production,' *World Nuclear News*, 27 January 2015.

2) Priargunsky; 3) Rössing; 4) MacArthur River; and 5) Ranger. The latter four are still operating.

The sixth largest is Rabbit Lake, also in northern Saskatchewan, Canada. Nicknamed the 'energizer bunny,' Rabbit Lake is the longest operating uranium production facility in North America. Opened in 1975, total production until 2014 amounted to 198.2 million pounds (90,000 tonnes), including 4.2 million pounds (roughly 2,000tU) in 2014. Olympic Dam, which has the world's largest uranium deposit, is likely the seventh-all time producer. Operating since 1988, the WNA states that Olympic Dam has produced 33,650 tU_3O_8 since BHP Billiton acquired the mine in 2005. Before that, production was roughly 42,000 tU_3O_8, for a lifetime total of approximately 75,000 tU_3O_8 until the end of 2014.[69]

The Third Uranium Wave

The third wave of global exploration began in 2003. In the two years 2005-2006, the world's known uranium resources increased by 15 per cent (17% in the cost category to $80/kgU).[70] According to the joint NEA-IAEA Red Book, a 23 per cent increase in uranium exploration and mine development expenditures between 2010 and 2012 led to total known uranium resources increasing by more than seven per cent since 2011, adding almost ten years of global reactor demand to the existing resource base.[71] While exploration expenditures decreased in Australia, increases were seen in Brazil, China, Ethiopia, Iran, Kazakhstan, Poland, Spain, Tanzania, Turkey, Ukraine, the United States and Zambia.[72] The report, however, noted that the majority of these increases were seen in categories with higher production costs.[73]

The Red Book states that over 95 per cent of exploration expenditures were devoted to domestic activities. Although overseas exploration and development decreased from USD 371 million in 2009 to less than USD 200 million in 2010-2012, it remained significantly above the USD 70 million reported in 2004. Overseas development costs in China were projected to expand beyond USD 560 million

[69] Cindy Vestergaard, *Governing Uranium in Australia,* forthcoming 2015.

[70] World Nuclear Association, Supply of Uranium: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/. Accessed 25 May 2015.

[71] Executive Summary, *Uranium 2014: Resources, Production and Demand*, NEA no. 7209, Nuclear Energy Agency, Organisation for Economic Co-operation and Development and International Atomic Energy Agency, 2014, p. 3.

[72] Ibid., p. 4.

[73] Ibid., p. 3.

in 2013 due largely to investment in the Husab mine in Namibia, pushing the anticipated non-domestic exploration and development expenditures to more than USD 650 million in 2013.[74]

As of 1 January 2013, total identified resources (reasonably assured and inferred) reached over 5.9 million tU in the <USD 130/kgU (<USD 50/Ib U_3O_8) cost category. In the higher cost category of <USD260/kgU or <USD100/Ib U_3O_8, total identified resources increased to more than 7.6 million tU, or 7.6 per cent higher than reported in 2011.[75] This represents an almost three-fold increase since 1975.[76]

At the same time, low spot prices have led companies to mothball a number of mines with high production costs, as witnessed by Energy Fuels' announcement in the autumn of 2012, when it put its Beaver and Daneros properties on the Colorado Plateau on standby, followed by the Pandora property in 2013.[77] This was followed by Uranium One announcing in November 2013 that its Honeymoon mine in South Australia was being put into care and maintenance after only two years of operation.[78] Heathgate's in situ mines at Beverley and Beverley North, also in South Australia, were put into care and maintenance in 2015, while Paladin mothballed operations at the Kayelekera mine in Malawi in spring 2014 'until the price of uranium recovers.'[79] In February 2015, the China National Nuclear Corporation (CNNC) announced that the Azelik mine in Niger, which had experienced prolonged project delays, overruns in its construction budget and low production, would be closed and put into care and maintenance due to 'light cash flow.'[80]

Between 2002 and 2013, uranium production in traditional countries largely declined (10% down in Canada and 16% down in Australia), whereas since the turn of the century production has emerged in new countries such as Malawi, Namibia, Uzbekistan., and the world's largest producer, Kazakhstan, has increased production by over 700 per cent (see Figure 5).

[74] Ibid., p. 4.

[75] Ibid., p. 3.

[76] World Nuclear Association, 'Supply of Uranium': http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/. (Accessed 25 May 2015).

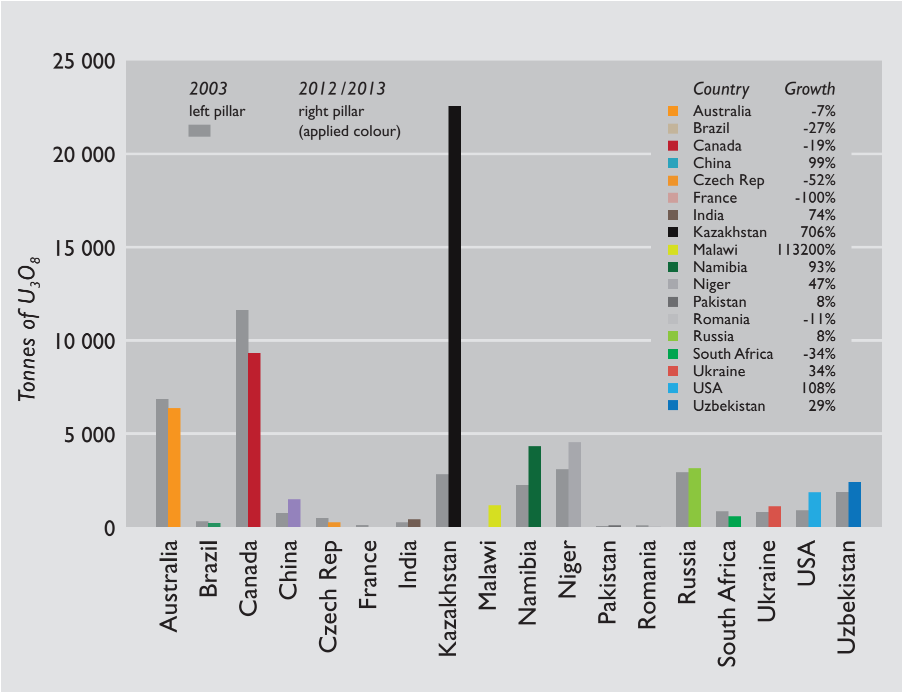
[77] 'Energy Fuels to Focus on Lower Cost Uranium Production,' *Reuters,* 17 October 2012.

[78] The reasons were costs related to production problems during the commissioning process, lower than anticipated yields and low uranium prices. See: 'Honeymoon uranium mine goes into care and maintenance, 90 jobs cut,' *Australian Mining*, 14 November 2014.

[79] 'Paladin Energy suspends production at Malawi mine,' *Mining.com*, 7 February 2014.

[80] 'Uranium in Niger,' World Nuclear Association: http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Niger/. Accessed 27 May 2015.

Figure 5. Change in Uranium Production 2003-2012/2013



Source: http://www.world-nuclear.org/info/Facts-and-Figures/Uranium-production-figures/

2.4 The Uranium Market

The uranium supply industry underwent considerable consolidation during the 1980s and the 1990s. The spot U_3O_8 price fell 85 per cent from January 1980, when it was US$40/Ib, to less than $7/Ib in 1992.[81] Large inventories of uranium, particularly from secondary supplies, further depressed prices and caused the production of newly mined uranium to fall to half of consumption. An imbalance between supply and demand led to a build-up in commercial inventories generated from the oversupply of the 1970s, which peaked at nearly 600 million Ibs of U_3O_8 in 1985. Uranium surpluses continued to dominate the industry into the early 1990s, with more than 10 million Ibs of inventory being sold into the market in 1994. Western production had by then fallen to 55 million Ibs of $U_3O_{8,}$ or less than half of the western demand, while the number of producers

[81] Dave Clark, 'I'll be seeing U', presented at CNA/CNS Conference, 1996, p. 1.

also fell dramatically.[82]After the fall of the Berlin Wall dividing East and West the uranium market became further integrated globally, as Russia began offering feed material to western enrichment customers. With China beginning sales in the late 1980s, the entry of the two countries brought excess eastern production and inventory into western markets. From a level of zero prior to 1989, as much as 30 milliion lbs of U_3O_8 was being imported by western consumers by 1992. The 1980s saw a major consolidation in the uranium industry, as a wave of reactor cancellations and low uranium prices led to a number of producers closing down or merging with others, leading to the emergence of a small number of large global players. This consolidation was not restricted to western companies but also took the form of the integration of eastern supplies into the western market after the fall of the Berlin Wall. As Dave Clark noted, 'the two waves of consolidation/ integration were not enough; the market then faced the challenge presented by the integration of commercial and military markets on a world basis.'[83]

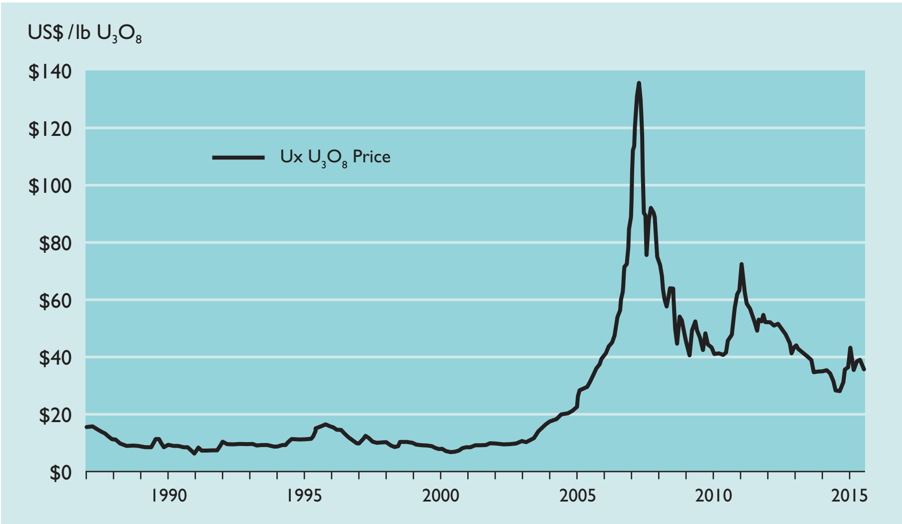
Relatively stable during the rest of the 1990s, the spot price of U_3O_8 began to increase and dramatically spiked in 2007 to $137 per pound. This 'uranium bubble' led to an increase in uranium exploration and identification of uranium resources across a number of states as both a primary product and a co-product of other minerals such as coal and phosphates. Despite the decline in uranium prices over the last decade, the market price is generally higher than in the preceding two decades.

In May 2015, Tokyo Electric Power (TEPCO) announced it was planning to sell part of its uranium stockpile during its 2015 fiscal year. TEPCO has not consumed any uranium since the 2011 Fukushima nuclear crisis and, as of 31 March 2015, had a stockpile of 17,570 tonnes of uranium, which is anticipated to reach 19,317 tonnes by the end of the 2015 fiscal year due to supply contracts. TEPCO's sale could add 6.56 million pounds of U_3O_8 equivalent to the spot market to 'pay for the costs of uranium enrichment in kind, while [TEPCO] will also consider terminating uranium purchase contracts and reducing purchase volumes to streamline its business.'[84] While some analysts consider the TEPCO sale to be a 'one-off' rather than a signal of widespread inventory dumping, the sale will add close to 3,000tU to an already oversupplied market.

[82] Ibid., p. 4.
[83] Ibid., p. 2.
[84] 'TEPCO's Uranium Stockpile Sale Likely a 'One-off' Move,' *Uranium Investing News*, 19 May 2015.

As of 25 May 2015, the spot price of U_3O_8 was US$35 per pound. The historical price since 1988 is charted below.

Figure 6. Ux U_3O_8 Price® - Full History (Spot)



Source: The Ux Consulting Company, LLC: http://www.uxc.com/

Today the market is dominated by eight major companies: AREVA, Cameco, Rio Tinto, KazAtomProm, BHP Billiton, Navoi, Paladin and Uranium One. Together, these eight companies provided 82% of world uranium production in 2012.[85] All but Paladin have long experience in uranium mining. Paladin started investing in several advanced uranium exploration projects in the late 1990s and is now a medium-size company in the sector. It has emerged as one of the leading uranium actors in Africa, operating the Langer Heinrich mine in Namibia and the Kayelekera mine in Malawi. Since 2010, Paladin also owns Project Agadez, a uranium exploration project in northern Niger. On 22 June 2015, it was granted an exemption from Canada's Non-Resident Ownership Policy to allow it to become the majority owner of a uranium mine at the Michelin Project in Labrador Canada, which it acquired in 2011. With the exemption, Paladin became the first Australian company to become a majority owner of a uranium mine in Canada.[86]

[85] Uranium Mining Overview, World Nuclear Association: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Mining-of-Uranium/Uranium-Mining-Overview/. Accessed 30 June 2015.

[86] 'Canada lets Australia's Paladin be majority owner of uranium mine,' Reuters Canada, 22 June 2015.

Most sales of UOC are made under long-term contracts, executed several years in advance of the first delivery, and purchased through a bidding process. As a result, the customer base has not changed much for uranium suppliers over the past several decades. Buyers tend to diversify their sources of supply, ensuring they do not become too dependent on any single mine, company or country. They also diversify the services that are needed along the supply chain, such as conversation, enrichment and fuel fabrication, in order to secure nuclear fuel separately. This gives the utility company high levels of cost control and a full understanding of the supply chain while maximizing its security of fuel supply. Power companies are therefore able to tell mining companies how much UOC to deliver to which converter and when. Given their stability, long-term contracts are likely to remain the dominant model. In recent years, however, the fluctuating price of uranium has awakened the interest of commodity traders, and the spot market, which used to supply about 5 per cent of global demand, has increased its share to between 10 and 20 per cent.[87]

It is usually utilities that buy UOC, but this is changing. Heathgate, for example, sells to converter/traders at the spot market price.[88] Total U.S. commercial inventories (including inventories owned by COOs, U.S. brokers, converters, enrichers, fabricators, producers and traders) were 121 million pounds of U_3O_8 as of the end of 2012. Of that, converter, enrichers, fabricators and producers owned 18 million pounds of U_3O_8, while U.S. brokers and traders owned about 6 million pounds.[89]

However, the role of brokers is opaque. In 2009, the United Nations General Assembly adopted Resolution A/RES/63/67, recognising that brokering activities covered 'not only conventional arms but also materials, equipment and technology that could contribute to the proliferation of weapons of mass destruction and their means of delivery', and it called upon Member States to 'establish appropriate national laws or measures to prevent and combat illicit brokering activities.' In 2010, the Nuclear Suppliers Group (NSG) issued a document on Good Practices for Brokering and Transit/Transhipment, which was adopted at the 2014 NSG Plenary. It concluded that brokering and transit/transhipment controls assisted in closing loopholes with new rules that go beyond the requirements for exports to catch additional activities, regardless of whether or not an illegal export is involved.

87 SIPRI report, 2013, p. 8.

88 Discussion with Australian official, 18 June 2013.

89 US Energy Information Service, *2012 Uranium Marketing Report*, US Department of Energy, May 2013, p. 2.

A reasonable and functioning export control system is therefore supplemented with brokering controls.[90]

A study carried out by the OECD's NEA in 1994 stated that uranium purchases contributed between 30 and 50 per cent of the total cost of the PWR fuel cycle, representing between 5 and 20 per cent of the total costs of electricity generation. At the time, the uranium market was characterised by large global inventories and low prices. Consumption was also higher than production.[91] The prices for the conversion of uranium to $UF_{6,}$ in the range of US$6 to $11 per kg U, constituted only a small percentage of total fuel cycle costs.[92] The 1994 NEA study was not specific regarding the costs of safeguards; it noted that they 'are negligibly small in comparison to other cost components of the fuel cycle.'[93] The NEA paper has not been updated, although a recent discussion with an industry representative confirms that at around five per cent conversion costs remain small in relation to the overall total fuel cycle costs.[94]

2.5 Corporate Social Responsibility

A sub-study of the corporate social responsibility (CSR) policies of the eight major uranium companies was undertaken as part of the *Governing Uranium* project. Of the eight majors, six mention 'non-proliferation' in their sustainability material. These include Areva (1 count), BHP Billiton (2 counts), KazAtomProm (2 counts), Paladin (5 counts) and Rio Tinto (1 count).[95] However, only three actually elaborated upon the company's position regarding non-proliferation issues in their sustainability reports namely Areva, ARMZ-Uranium One and Paladin. In terms of material assessments, none of the companies highlight non-proliferation as a key sustainability risk. That said, Paladin and Rio Tinto both refer to product stewardship in their material assessment. According to research conducted by France Bourguoin, Paladin can be seen as having one of the most robust approaches to this issue among these eight mining companies, given the extensive mention of non-proliferation

[90] Nuclear Suppliers Group, *Brokering and Transit/Transshipment in the context of the NSG*, 2014, p. 8.

[91] OECD Nuclear Energy Agency, *The Economics of the Nuclear Fuel Cycle,* 1994, p. 35.

[92] Ibid., p. 36.

[93] Ibid., p. 45.

[94] Discussion with industry representative, 17 July 2014.

[95] France Bourgouin, *Corporate engagement in non-proliferation along the nuclear supply chain: material stewardship and traceability in uranium procurement*, DIIS Report 2015:04, p. 24.

in its sustainability material.[96] This demonstrates that the inclusion of non-proliferation as a sustainability issue is a more effective way of stimulating corporate engagement in the issue than when it is solely seen as a political issue and addressed in corporate governance material only.

In corporate governance material, AREVA, for instance, includes non-proliferation as a control principle in its value charter, which suggests a growing recognition of the industry's critical role in and responsibility for promoting non-proliferation worldwide. Bourgouin's research also describes two notable examples of corporate approaches to uranium governance offered by BHP Billiton and KazAtomProm. In the first case, BHP reconciles records of uranium production, transfers, receipts, stakes in overseas facilities and overseas sales to its customers in countries that are signatories to the NPT on a six-monthly basis to the Australian Safeguards and Non-Proliferation Office (ASNO) and the Department of Resources, Energy and Tourism (DRET). In the second case, KazAtomProm's corporate documentation mentions its participation in an IAEA pilot project on natural uranium accounting and control, directed to further strengthening the NPT.[97]

Even with these examples at hand, the overall interest of uranium suppliers in taking a more proactive role in non-proliferation is limited. In general, the justification given for the absence of non-proliferation in sustainability materiality and programmes is that uranium is not considered a 'risk' material. As Bourgouin notes:

> …by excluding non-proliferation as a material sustainability issue, mining companies are missing an opportunity to use effective sustainability practices already in place (such as sustainability reporting) towards building an industry-wide culture of security. The further consideration of the relevance of non-proliferation to corporate sustainability would thus encourage the development of corporate practices for the promotion of nuclear security.[98]

Bourgouin's research also found a lack of a standardised industry approach by nuclear utilities to engaging in non-proliferation debates where opaque supply chains make it difficult to assess the degree of supply-chain transparency.[99] Similarly

[96] Ibid.

[97] Ibid., p. 25.

[98] Ibid., p. 26.

[99] Ibid., pp. 31-32.

in the financial sector, there are inconsistencies among the world's leading banks when it comes to engaging in nuclear issues. Leading Chinese banks, for example, make no provisions for financing projects related to the nuclear value chain. Banks that do provide financing to companies along the nuclear supply chain and that have nuclear policies do mention non-proliferation, though there are no performance standards to accompany their evaluation. The role of the financial sector could therefore be enhanced further, with the inclusion of references to non-proliferation in the Equator Principles, as well as by incorporating uranium mining (along with environment and safety) into the bank's nuclear policies.[100]

Bourgouin underscores that her research is based on the information that companies are comfortable making publicly available. As such, her report does not go on to make claims regarding any corporate practices that may be kept confidential. She therefore argues that, for it to become a fully effective tenet of corporate sustainability, non-proliferation will need its own set of committed companies, standards-based performance indicators, and knowledgeable investors and consumers. Without this infrastructure, dual-use manufacturers, shippers, brokers and financiers may lack the market mechanisms that reward superior non-proliferation performance. Given that a number of utility companies and buyers of enriched uranium do already adhere collectively to robust ethical, social and environmental performance standards, the addition of non-proliferation would strengthen sustainability standards for the entire industry.

Bourgouin goes on to suggest that a good starting point would be to require companies, as a condition of conducting business, to have a proliferation-resistant compliance system in place on which they would report, along with a non-proliferation statement in their corporate governance structures. Corporate performance on non-proliferation could then be reported and monitored for the entire nuclear supply chain. The OECD similarly endorses strong non-proliferation controls within the nuclear industry, stating that they are vital for open and competitive global markets to exist. Noting that such controls will involve some market restrictions, the OECD emphasises that 'non-proliferation controls are consistent with the development of new capacities by competing suppliers to meet the growing requirements of nuclear programmes around the world.'[101]

[100] Ibid., p. 35.
[101] OECD Nuclear Energy Agency, *The Economics of the Nuclear Fuel Cycle,* 1994, p. 45.

2.6 Recommendations

1. Benchmarking non-proliferation performance

Companies along the nuclear supply chain can strengthen the global nuclear regulatory regime through engagement, material stewardship and traceability. Private actors share a responsibility in being aware of where their uranium is sourced, how it is mined and the social and environmental impacts of mining and transport operations, as well as being able to provide assurances that uranium has not been lost or accidentally diverted along the supply chain.

2. Controls on Brokering and Transit/Transhipments

The development and implementation of appropriate national laws or measures supplement a country's export controls by closing loopholes to catch additional nuclear trading activities, regardless of whether or not illicit brokering is involved.

3. Uranium Ore Concentrate: The Starting Point of Safeguards

The International Atomic Energy Agency (IAEA) is the world's nuclear inspectorate, applying technical measures referred to as 'safeguards' to verify the accuracy and completeness of the declarations states make regarding their nuclear material and activities. The 1957 Statute of the IAEA provides the fundamental basis for the establishment of safeguards which today have become grounded within the 1970 Nuclear Non-Proliferation Treaty (NPT) and regional Nuclear Weapons-Free Zones (NWFZs) and been adopted in multilateral trading guidelines. The IAEA safeguards system has evolved greatly over the years from the 'item-specific' approach of the 1960s to one that is becoming increasingly 'integrated' and 'state-level,' applying to all nuclear material in the State as a whole. Historically, this system of safeguards has provided limited international and regional guidance applicable to the governance of uranium ore concentrate (UOC). Over the past decade, however, as technology and uranium processing have advanced, more and more front-end nuclear materials are being captured.

This chapter provides an overview of international obligations related to safeguarding natural uranium and describes how they are implemented in practice multilaterally, regionally and bilaterally.

3.1 Paragraph 34: The Starting Point

Natural uranium is defined as source material and thus as a type of nuclear material, under the IAEA Statute and in the IAEA Information Circular, INFCIRC/153 of 1972, which defines the starting point of full-scope safeguards (i.e. the application of the full set of accountancy and control provisions on nuclear material inventory). These safeguards, however, do '*not* apply to material in mining or ore processing activities' (emphasis added).[102] Paragraph 34(c) is commonly referred to as 'the starting point of safeguards', and states that:

> When any nuclear material of a composition and purity suitable for fuel fabrication or for being isotopically enriched leaves the plant or the process

[102] The Structure and Content of agreements between the Agency and States Required in Connection with the Treaty of the Non-Proliferation of Nuclear Weapons, IAEA INFCIRC/153 (June 1972), para 33.

> stage in which it has been produced, or when such nuclear material, or any other nuclear material produced at a later stage in the nuclear fuel cycle, is imported into the State, the nuclear material shall become subject to the other safeguards procedures specified in the Agreement.

Full safeguards therefore begin when nuclear material pure enough to be fabricated or enriched 'leaves the plant or process stage', historically interpreted as the output of conversion plants (i.e., UO_2 or UF_6). In 1970 and 1971, when the paragraphs of INFCIRC/153 were being negotiated, there was a lengthy debate on whether safeguards should be fully applied inside the facility, where the material reaches a certain state of nuclear purity, or when it leaves the facility. Concentration thresholds were discussed but dismissed, in part because this would have introduced discriminative regulatory controls by applying safeguards to some and not others within a competitive global industry.[103] There was the added complication of how to treat uranium where ore processing and concentration processes were combined in one facility; raising the question of when ore processing (which is not subject to safeguards) stopped and concentration began. In the end, it was agreed that full safeguards start when the material 'leaves the plant or process stage', essentially meaning the product of conversion plants. The negotiating record describes this as a function definition (as opposed to a concentration-based definition).[104]

Given that source material is used to feed subsequent stages of the nuclear supply chain, negotiators added provisions for the reporting of trading in uranium ore concentrates (UOC), or 'pre-34(c)' material. Paragraph 34(a) states that, 'When any material containing uranium or thorium [...] is exported to a non-nuclear weapon State, the State shall inform the Agency, *unless* the material is exported for specifically non-nuclear purposes' (emphasis added). Paragraph 34(b) mirrors the same language for imports. This includes material containing even trace quantities of uranium or thorium (such as phosphates, mineral sands, coal and rare earth elements) if such material is exported for nuclear purposes. Accordingly, the 'starting point' of reporting to the IAEA begins with the trading of UOC, while 34(c) defines the starting point for material to be captured under full material accountancy and control. In other words, if a pre-34(c) material is traded

[103] Craig Everton, Stephen Bayer and Michael East, 'Safeguarding Uranium Production and Export Conventional and Non-Conventional Resources', European Safeguards R&D Association (ESARDA) and Institute of Nuclear Materials Management (INMM) meeting, Aix en Provence, France, October 2011, p. 5.
[104] Ibid.

for eventual use in a nuclear reactor, this must be recorded and reported. If such material is not destined for use in the nuclear supply chain (such as for ceramics), then it is exempt from the requirement to report. The IAEA transit matches this information but it is does not verify it. This reporting of exports and imports has been the only safeguard historically applied to source material.

Large supplier countries such as Australia and Canada report their exports and imports of UOC on a monthly basis. Unfortunately, when looked at as a whole, reporting under paragraphs 34(a) and (b) is uneven across IAEA members. While the paragraphs are generally used for UOC exports and imports only, *any* material containing even trace quantities of uranium or thorium (i.e. phosphates, copper, coal, rare earth elements, etc.) should be reported if such material is exported for nuclear purposes. It is thus incumbent on states that may export uranium-bearing ores or UOC to apply prudent controls and evaluate the risk that uranium will be extracted for nuclear purposes, and if so, to apply appropriate controls to such exports. Most cases are not made public, but there are leaked examples of small amounts being unevenly reported, as in the case of Finland reporting an import of one tonne of uranium from the Democratic Republic of Congo (DRC) to the IAEA, even though the DRC claimed that it did not export any uranium in 2006.[105]

Until the 1990s, virtually all IAEA safeguards were focused on the accounting of nuclear materials associated with facilities that states have declared to the Agency. Following inspections after the first Gulf War in Iraq that revealed Iraq's nuclear weapons programme, as well as revelations of undeclared activities in Egypt, Iran, Libya, North Korea, South Korea and Syria, the IAEA began moving towards detecting undeclared activities. In 1997, the IAEA passed the Model Additional Protocol (INFCIRC/540),[106] an addition to the safeguards agreement which grants broader information on (and IAEA access to) a State's domestic uranium production, as well as data on trade in secondary materials that may contain uranium or thorium.

Articles 2(a)(v) and (vi) of an additional protocol (AP) require annual reporting of uranium and thorium holdings, along with reporting on exports and imports of

[105] 'Recent Allegations of Uranium Trafficking in the Democratic Republic of Congo,' US diplomatic cable, Wikileaks, 27 July 2007.

[106] Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, IAEA Doc INFCIRC/540 (September 1997).

pre-34(c) source material for *non-nuclear purposes*.[107] Articles 4 and 5 spell out the IAEA's 'complementary access' to verify the absence of undeclared nuclear material. These requirements formalise the need for AP States to apply prudent controls and evaluate the risk that uranium will be extracted for nuclear purposes. For those without comprehensive safeguards agreements (or the additional protocol), there are no legal obligations to track secondary uranium sources. Only for States with both comprehensive safeguards agreements (CSA) based on INFCIRC/153 and APs in force can the IAEA draw a broader conclusion on whether *all* nuclear material in a State is being used solely in peaceful activities. For those with CSAs but no AP, the Agency draws the conclusion that *declared* nuclear material remains in peaceful activities.

The IAEA has determined for safeguards purposes that the timeliness goal for detection of the diversion of a 'significant quantity' of natural uranium is one year.[108] The 'significant quantity' for natural uranium is 10 metric tonnes (equivalent to approximately 12 tonnes of UOC), which translates into one shipping container (holding around 20-35 drums of yellowcake). This is considered roughly the amount of U_3O_8 needed to produce fissile material for use in a nuclear explosive device.

3.2 Clarifying Paragraph 34(c)

Over the past decade, technological advances in the uranium industry, coupled with persistent proliferation threats from State and non-State actors, have increased concerns over the diversion of source materials, that is, the introduction of undeclared feed for conversion, fuel fabrication or enrichment plants. Thirty years after INFCIRC/153 was established, the IAEA reinterpreted paragraph 34(c) for the first time, affecting safeguards implementation in non-nuclear weapons states

[107] The issue of how to address uranium recovered from secondary sources was debated during INFCIRC/153 negotiations in 1970-1971. At the time, the main discussions regarding paragraph 34(a) and exports of pre-34(c) material between countries desiring reporting on all material containing uranium or thorium, irrespective of intended use, and others that wanted reporting to be conditional on their being a nuclear purpose. Several states such as Australia, Canada, South Africa and the United Kingdom were concerned that costs could be levied on the mineral sands and phosphates industries if reporting applied to non-nuclear industries, while others were concerned that, if export notifications rested solely on nuclear purposes, there might be no presumption of reporting to the IAEA on all pathways of uranium production. In the end, the exclusion of material 'for specifically non-nuclear purposes' in Paragraphs 34a and 34b was agreed in 1972, with the Additional Protocol removing the exemption twenty years later. See Craig Everton, Stephen Bayer and Michael East, p. 3.

[108] UOC is considered to be indirect use material. See Table II, paragraph 3.14, of the IAEA Safeguards Glossary, 2001 Edition, International Nuclear Verification Series No. 3, for more information on the definition of significant quantity, paragraph 4.26 for the definition of indirect use material, and paragraph 3.20 for more information on timeliness detection goals.

with refining or conversion facilities and a CSA. With the introduction of 'Policy Paper 18' in 2003, full safeguards were brought forward to the production of uranyl nitrate or the first practical point before that. In Canada, this meant moving the starting point of full material accountancy to when drums of UOC are added to production lines, which marked the first time that Agency safeguards captured a refinery plant in Canada (i.e. Cameco's Blind River refinery).[109] The new starting point obviated having to report the tens of thousands of drums stored at the site. UOC, commonly referred to as 'yellowcake', therefore remains a 'pre-34(c)' material that is not subject to the *full* scope of IAEA accountancy and control provisions.

Policy Paper 18 also captured the material in process at the Esfahan Uranium Conversion Facility (UCF) in Iran, and presumably conversion experiments such as the conversion of uranyl nitrate directly to UO_3 that Iran had conducted previously.[110] Iran signed the AP in December 2003 and agreed to implement the agreement on a provisional basis pending ratification by the Iranian parliament. In 2006, Iran announced that it would cease adhering to the AP two days after the IAEA Board of Governors adopted a resolution that referred Iran's non-compliance with its safeguards agreement to the UN Security Council.[111] As such, the provisions of Policy Paper 18 have yet to be implemented in Iran. According to the Joint Comprehensive Plan of Action (JCPOA) reached on 14 July 2015 between Iran and the E3/EU+3 (France, Germany and United Kingdom plus China, Russia, and United States with the High Representative of the European Union for Foreign Affairs and Security Policy), Iran will provisionally apply the Additional Protocol to its Comprehensive Safeguards Agreement and proceed with its ratification by the Majlis.[112]

At the same time, technological advances in the uranium industry are producing purer uranium ore concentrates, with some suppliers advertising their product as pure enough for fuel fabrication, that is, without the need for further purification

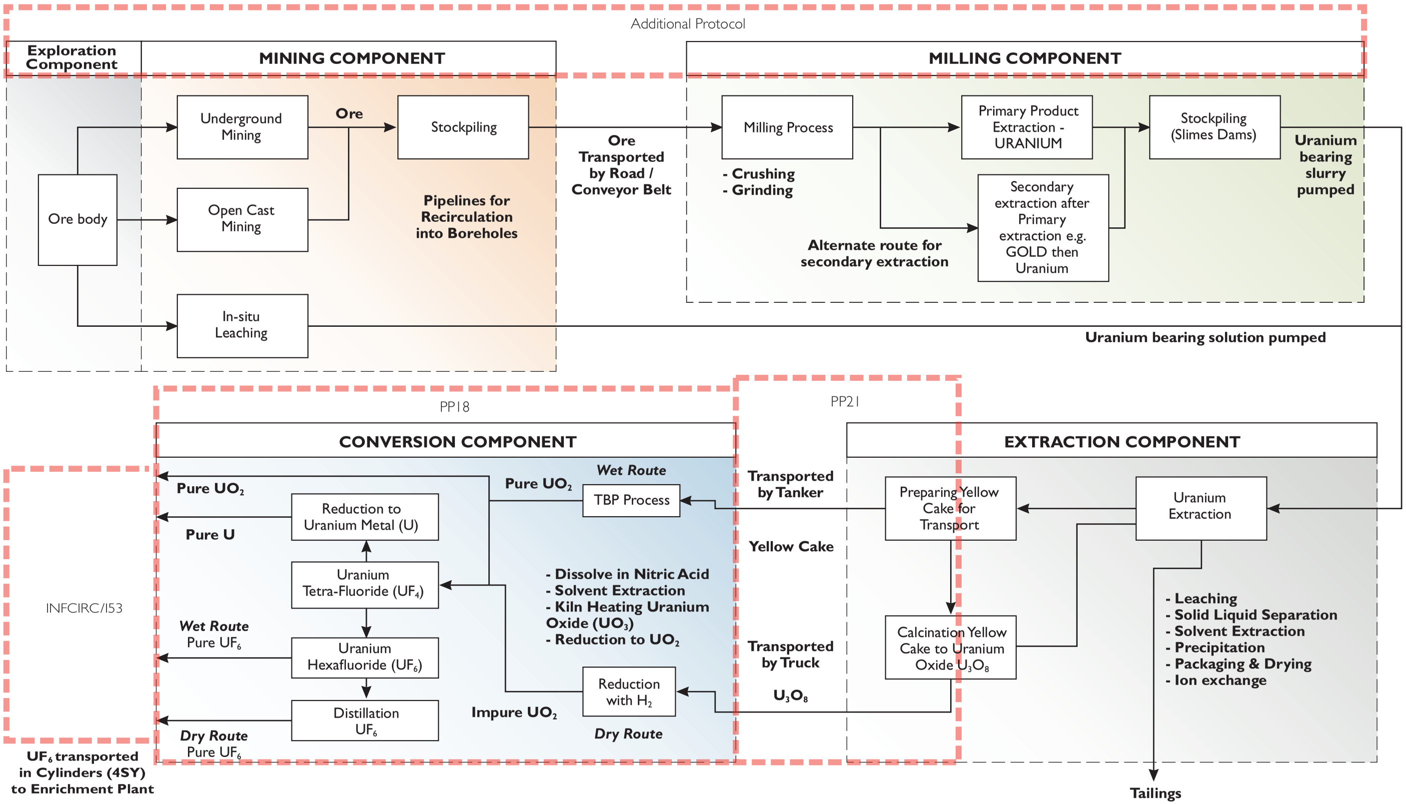
[109] Thereby also capturing the addition of safeguarded uranium scrap (recycled from conversion and fuel fabrication plants) to the process. See K.E. Owen, 'Implementation of IAEA Policy Paper 18 in Canada', in *Addressing Verification Challenges: Proceedings of an International Safeguards Symposium on Addressing Verification Challenges*, organised by the International Atomic Energy Agency (IAEA) in Cooperation with the Institute of Nuclear Materials Management and the European Safeguards Research and Development Association, 16-20 October 2006.

[110] Throughout the 1980s and early 1990s.

[111] Paul Kerr, 'Iran's Nuclear Program: Tehran's Compliance with International Obligations,' Congressional Research Service, 28 April, 2014, p. 4.

[112] Joint Comprehensive Plan of Action, Vienna, Austria, 14 July 2015, pages 9 and 153.

Figure 7. Application of Safeguards to the Front-End of the Nuclear Fuel Cycle [113]



113 The overview of the process flows diagram comes from Annex III of the IAEA Tecdoc DRAFT, 'Nuclear Security in the Uranium Extraction Industry', forthcoming 2015. The red lines associated with safeguards have been newly added to the diagram for this report.

(conversion). In 2013 the IAEA drafted Policy Paper 21, which further clarifies the chemical forms of uranium that fall under paragraph 34(c), capturing material upstream to the product of uranium mills and concentration plants, that is, drums of 'pure' UOC suitable for fuel fabrication. The revised definition will create new obligations for state regulatory authorities and industry and facility operators, and new verification responsibilities for the IAEA. The application of safeguards to material at the front-end of the supply chain is depicted in Figure 7.

The international safeguards system is thus shifting upstream, capturing more materials at the front end of the nuclear fuel cycle. While Policy Paper 21 has yet to be fully implemented, and its success in addressing gaps in the control of natural uranium will be determined in the years to come, the next section looks at how the application of safeguards obligations under CSAs and APs have been implemented in practice across a group of states, particularly the nuclear weapons states, states that are not a party to the NPT, the Brazilian–Argentine Agency for the Accounting and Control of Nuclear Materials (ABACC), Euratom, Nuclear Weapons Free Zones (NWFZs) and the Nuclear Suppliers Group (NSG), as well as in bilateral treaties.

3.3 Nuclear Weapons States

The safeguards listed above are applicable only to non-nuclear weapons states (NNWS), a designation broadly delineated in the 1970 Treaty on the Non-Proliferation of Nuclear Weapons. Under the NPT, five nuclear weapons states (NWS) are recognised as legitimate haves: China, France, Russia, the United Kingdom and the United States – states that produced and exploded a nuclear weapon (or device) before 1 January 1967.[114] The rest, the have-nots, are simply known as 'non-nuclear weapons states.' In principle, this categorisation should indicate countries free of nuclear weapons. In practice, India, Israel and Pakistan, the three countries that have never signed the NPT, plus North Korea, which withdrew, all have nuclear weapons but are excluded from NWS status given the 1967 treaty definition. Thus, the NPT created a three-tiered system of 'haves' (NWS), 'have-nots' (NNWS) and 'haves that are considered have-nots' (four non-NPT states).

Under the NPT, the NNWS are required to adopt safeguards agreements, while the NWS are not unless they choose to on a voluntary basis at selected facilities.

[114] Article IX, paragraph 3.

Each of the five NWS has a voluntary offer safeguards agreement and an additional protocol in place, each varying in scope. The United States has volunteered all of its civilian facilities as eligible for safeguards under the IAEA-US Agreement[115] (except those with 'direct national security significance'), as do the United Kingdom and France, given the combined effect of IAEA and Euratom safeguards. In the UK, for example, Euratom safeguards are applied at UK civil nuclear sites, including those that historically were sometimes used for military purposes, such as the conversion facility at Springfields.[116] The unique status of NWS, however, allows them to exempt materials from third-party oversight. According to Tertrais and Padova, Niger uranium imported into France is 'free of use', as it belongs to category 'N', the Euratom obligation code for 'materials not submitted to a Euratom or IAEA commitment.'[117]

The UK also has an additional protocol, meaning that Article 2 declarations are issued for all work that is conducted in collaboration with, or is otherwise relevant to, a NNWS.[118] It is worth noting that, in the case of research and development, some NWS, such as the United Kingdom and the United States, go further than the model AP by declaring research and development carried out in collaboration with a NNWS if it involves nuclear material. This is because the IAEA might otherwise not be aware of such work.[119] With respect to the United States AP, the agreement specifies that complementary access will be on a selection basis (Article 4(a)(i)).[120] Consistent with Article 2, the United States provides information to the IAEA on the location, operational status and estimated annual production capacity of uranium mines and concentration plants.[121]

Russia and China have more restrictive lists, as well as more restrictive monitoring access. The additional protocols for China (2002) and Russia (2007), for example,

[115] *Text of the Agreement of 18 November 1977 between the United States of America and the Agency for the Application of Safeguards in the United States of America*, IAEA Doc INFCIRC/288 (December 1981) (entered into force 9 December 1980), Article 1.

[116] Euratom inspectors visit Springfields once a month, and there are two rigorous inspections a year. See *Governing Uranium in the United Kingdom*, DIIS Report 2014:02, p. 26.

[117] Bruno Tertrais and Cécile Padova, *Governing Uranium in France*, DIIS Report 2014:17, pp. 42-43.

[118] The UK Nuclear Safeguards Act 2000 is the implementing legislation for the Additional Protocol with the IAEA and Euratom; it came into force in 2004.

[119] Molly Berkemeier, Wyn Q. Bowen, Christopher Hobbs and Matthew Moran, *Governing Uranium in the United Kingdom*, DIIS Report 2014:02, p. 27; see also *U.S. Additional Protocol Implementation Act*, Senate Report, 3 April 2006.

[120] The US signed an Additional Protocol in 1998; it entered into force in 2009.

[121] Sharon Squassoni et al., *Governing Uranium in the United States*, CSIS Report, March 2014, p. 55.

do not allow IAEA inspectors physical access to any facilities.[122] They also share a twist to their reporting on domestic uranium mines and concentration plants, linking it specifically *to production for a NNWS*. Given that neither country currently exports domestically produced uranium, neither reports to the IAEA on its uranium holdings.[123]

Although the NPT does not require the NWS to report on trade, the United States, Soviet Union and United Kingdom informed the IAEA in 1974 (INFCIRC/207) that they would report exports of nuclear material to NNWS of quantities exceeding one effective kilogram (including source material which is not ore or ore residue, and excluding material for non-nuclear uses) and imports of such material from states where it was subject to IAEA safeguards.[124] In 1995, the U.S. Government agreed voluntarily to report imports and exports of one effective kilogram or more of source material (natural uranium, depleted uranium and thorium) to the IAEA on a monthly basis. The additional protocol for China added reporting for the first time on nuclear exports and imports (including source material) to NNWS, while Russia's Additional Protocol, along with those of the United Kingdom, United States and France, included the provision 'specifically for non-nuclear purposes' to their export/import reporting of pre-34(c) material.

The unique status of NWS' safeguards obligations continues to frustrate a number of NNWS member states. At the IAEA Board of Governors (BOG) meeting in June 2012, a few raised the issue of safeguards and encouraged the NWS to expand the scope of their voluntary offer agreements. One reminded the meeting of Action 30 of the Final Document, adopted by consensus at the 2010 NPT Review Conference, which called 'for the wider application of safeguards to peaceful nuclear facilities in the nuclear-weapon States' and stressed 'that comprehensive safeguards and additional protocols should be universally applied once the complete elimination of nuclear weapons has been achieved.'[125] In an increasingly globalised civilian nuclear

122 Tamara Patton Schell, *Governing Uranium in China*, DIIS Report 2014:03, p. 43. See also 'The Protocol to the Agreement of the International Atomic Energy Agency Regarding Safeguards in the United States (Treaty Doc. 107-7), report issued by Mr. Lugar to the Senate Foreign Relations Committee', 26 March 2004, pp. 99-100.

123 See Anton Khlopkov and Valeriya Chekhina, *Governing Uranium in Russia*, DIIS Report 2014:19, p. 52; and Rajiv Nayan, *Governing Uranium in India*, DIIS Report 2015:02, p. 62.

124 The information provided prior to export would include the exporter, importer, and a description of the material (including quantities and composition); shipments would be confirmed afterwards.

125 Mark Hibbs, 'LBJ's Safeguards Legacy,' *Arms Control Wonk*, 25 June 2013.

market, the value of IAEA safeguards would be greater if all peaceful-use activities were safeguarded in the NWS as well as the NNWS.[126]

3.4 Haves considered have-nots

The non-NPT states of India, Israel and Pakistan have INFCIRC/66-type safeguards agreements which are 'facility' or 'item specific' and therefore do not cover the totality of the State's nuclear activities.[127] INFCIRC/66/Rev.2 was approved by the IAEA's Board of Governors in 1965. These second-generation agreements were concluded before the advent of the NPT to safeguard a specified facility with the scope determined by the State, and the IAEA was to be notified of items required to be safeguarded in accordance with the inventory maintained under each agreement. These inventories include any nuclear material produced, processed or used in or by the use of those items and any nuclear material substituted for safeguarded nuclear material.[128] INFCIRC/66-type agreements have normally been entered into as a unilateral voluntary measure by a State or upon the conclusion of a supply agreement between two or more States that requires the application of IAEA safeguards.

North Korea signed a trilateral Type-66 safeguards agreement (INFCIRC/252) with the IAEA and the USSR in July 1977 that brought the IRT-2000 research reactor and a critical assembly in Yongbyon under IAEA safeguards.[129] After joining the NPT in December 1985, a full scope Safeguards Agreement (INFCIRC/403) was negotiated and entered into force on 10 April 1992. Inconsistencies emerged, however, regarding the DPRK's declarations of plutonium during inspections to verify its initial declaration.[130] After a decade of bilateral and then multilateral talks failed to bring North Korea into the IAEA fold, it withdrew from the NPT on 10 January 2003. The Agency has never been able to verify the completeness and accuracy of the DPRK's initial declaration and has drawn the conclusion that the

[126] For a good discussion on the expansion of safeguards in the NWS see: John Carlson, 'Expanding Safeguards in Nuclear-Weapon States,' Paper presented to the Annual Meeting of the Institute of Nuclear Materials Management, Palm Desert, California, 17-21 July 2011.

[127] INFCIRC/66.Rev.1.

[128] Laura Rockwood, 'Legal Framework for IAEA Safeguards,' IAEA, 2013, p. 11.

[129] The Soviet Union supplied the reactor's fuel.

[130] North Korea refused the IAEA access to additional information and sites, prompting the IAEA Director General to request a special inspection, which was also was refused by Pyongyang. In response, the Board of Governors concluded that the DPRK was in non-compliance with its Safeguards Agreement and referred it to the UN Security Council.

DRPK has been in non-compliance with its obligations under the Agreement since 1993. UN sanctions currently bar the transfer of any nuclear (including source) material to the DPRK.[131]

All the safeguards agreements concluded by Israel and Pakistan are modelled on the Safeguards Document INFCIRC/66/Rev.2 (or its earlier versions). On 4 April 1975 Israel concluded one trilateral INFCIRC/66-type safeguards agreement with the IAEA and the United States (INFCIRC/249),[132] which applies safeguards to Israel's research reactor, a uranium storage facility and a heavy water and material storage facility located at the Soreq Nuclear Research Centre. Israel has not concluded an additional protocol.

For Pakistan, a total of nine such INFCIRC/66-type agreements have been concluded (eight are still in force),[133] with one specific to UOC. Under INFCIRC/248 of March 1977, the Agency applies safeguards to shipments of uranium supplied by Niger to the Karachi Nuclear Power Plant (KANUPP). Section 6(a) requires Pakistan to notify the IAEA within two weeks of the receipt of Niger's source material in quantities above one metric tonne (quarterly reports for quantities below one metric tonne). Niger and any other states where Niger's uranium may be processed may also notify the Agency, while Pakistan also committed itself to providing the Agency with 'as much advance notice as possible' of transfers of large quantities of supplied material (Art. 6(c)). Although little publicly is available about Pakistan's implementation of this agreement, there were accounts of unsafeguarded uranium passing through Libya from Niger to Pakistan in the late 1970s.[134] Since 1991, all UOC imports to INFCIRC/66 type states have been subject to full accountancy recording and reporting requirements and subject to verification.[135] According

[131] UN Security Council Resolution 1718 (2006) bans exports/imports listed on the NSG Trigger to/from North Korea. See: S/ S/2006/814: Guideline for nuclear transfers: http://www.sipri.org/databases/embargoes/un_arms_embargoes/iran/items_list. Accessed 15 May 2015.

[132] Extended by a Protocol of 28 September 1977 (INFCIRC/249/Add.1).

[133] A trilateral agreement between Pakistan, France and the IAEA (INFCIRC/239) entered into force in March 1976, but the agreement has never been implemented. For the full list of IAEA safeguards for Pakistan, see Annex 4 in *Governing Uranium in Pakistan*, DIIS Report 2015:08, pp. 50-51.

[134] Fred Holroyd (ed.), *Thinking About Nuclear Weapons: Analyses and Prescriptions* (1985), Croom Helm, p. 160; together with Davis K. Willis, 'The Uranium Flow, Who Controls it?' *The CS Monitor* (2 December 1981): http://www.csmonitor.com/1981/1202/120234.html. Accessed 19 May 2015. It should be noted that A.Q. Khan's assistance to Libya's nuclear programme in the 1990s is not connected to Libyan cooperation in the 1970s.

[135] Discussion with IAEA official, 4 August 2015.

to a presentation by Pakistan's nuclear authority in 2014, Islamabad reports its imported UOC from Niger biannually.[136] Pakistan does not have an additional protocol.

3.5 Exempted Have-Nots that Have

Until recently, India too only had INFCIRC/66-type agreements, with six reactors placed under IAEA safeguards. On 18 July 2005, a joint India-U.S. statement proposed to separate India's nuclear facilities into civilian and military/strategic, placing more Indian facilities and materials under IAEA safeguards.[137] In September 2008, the Nuclear Suppliers Group (NSG) granted India an exemption from its rules requiring a comprehensive safeguards agreement as a condition of nuclear trade (see section on NSG below). The 2008 decision made India the only non-NPT state engaged in the global trade of civilian nuclear technology, effectively creating a fourth tier of safeguards specific to India. The same year, India signed an umbrella safeguards agreement with the IAEA (INFCIRC/754), placing ten nuclear power reactors under safeguards. It also provides that any nuclear (including source) material subject to IAEA or bilateral agreement may be further produced, processed, used or stored in a facility not listed on the IAEA's safeguards list provided the material is placed under temporary safeguards while present in the facility.[138] The importation of uranium is to be notified within four weeks of its arrival, and India has to inform the IAEA of all facilities which are using imported uranium and the precise amount in each facility.[139] In short, this means that foreign-sourced uranium imported into India *must* be IAEA-safeguarded but the IAEA does not consider the origin of the uranium subject to safeguards.

Like the additional protocols for Russia and China, India's additional protocol (signed in 2009, with entry into force on 25 July 2014) does not allow the IAEA complementary access nor reporting on information related to nuclear fuel cycle-

[136] 'Safeguards in Pakistan: State-Agency Cooperation,' Presentation given at the IAEA Symposium on International Safeguards by Salim Khan, Muhammad Saeed Mulla, Pakistan Atomic Energy Commission, Disarmament and Safeguards Division, 20-24 October 2014.

[137] Joint Statement by President George W. Bush and Prime Minister Manmohan Singh, 18 July 2005: http://2001-2009.state.gov/p/sca/rls/pr/2005/49763.htm. Accessed 19 May 2015.

[138] International Atomic Energy Agency, 'Agreement between the Government of India and the International Atomic Energy Agency for the Application of Safeguards to Civilian Nuclear Facilities: Addition to the List of Facilities Subject to Safeguards under the Agreement', INFCIRC/754/Add.1, November 12, 2009.

[139] Rajiv Nayan, *Governing Uranium in India*, DIIS Report 2015:02, p. 32.

Table 4. Four Tiered Safeguards Structure

Haves (NWS)	*Have-nots (NNWS)*	*Have-nots that Have (non-NPT)*	*Exempted Have-nots that Have (India)*
VOAs AP	INFCIRC/153 AP JCPOA[140]	INFCIRC/66-type (no AP)	INFCIRC/754 AP

related R&D or uranium mining.[141] India's AP does require India to report on exports of pre-34(c) material beyond a significant quantity (ten metric tonnes of uranium).[142] Like Russia and China, India also has a policy of not exporting any of its domestically produced uranium. Table 4 details the structural international system of safeguards.

3.6 Brazilian–Argentine Agency for the Accounting and Control of Nuclear Materials

In July 1991, the Governments of Argentina and Brazil signed an Agreement for Peaceful Uses of Nuclear Energy and established a bilateral inspectorate, the Brazilian–Argentine Agency for the Accounting and Control of Nuclear Materials (ABACC). The resulting quadripartite comprehensive safeguards agreement between Argentina, Brazil, ABACC and the IAEA (INFCIRC/435) entered into force in 1994 and has become a unique safeguards agreement established at the request of states party to a bilateral non-proliferation arrangement (as distinguished from a bilateral supply arrangement). The Quad agreement's provisions[143] are similar

[140] The JCPOA concluded with Iran on 14 July 2015 could be considered as a subgroup under the NNWS safeguards agreements.

[141] Abha Dixit, 'India's Additional Protocol Enters into Force', International Atomic Energy Agency, July 25, 2014, http://www.iaea.org/newscenter/news/indias-additional-protocol-enters-force; and International Atomic Energy Agency, 'Protocol Additional to the Agreement between the Government of India and the International Atomic Energy Agency for the Application of Safeguards to Civilian Nuclear Facilities', INFCIRC/754/Add.6, August 1, 2014: http://www.iaea.org/sites/default/files/infcirc754a6.pdf.

[142] International Atomic Energy Agency, 'Protocol Additional to the Agreement between the Government of India and the International Atomic Energy Agency for the Application of Safeguards to Civilian Nuclear Facilities', INFCIRC/754/Add.6, August 1, 2014: http://www.iaea.org/sites/default/files/infcirc754a6.pdf. Accessed 14 April 2015.

[143] Agreement of 13 December 1991 between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/435, March 1994.

to those established by INFCIRC/153. The starting point of safeguards as defined in Article 9(b) of the Quad agreement is the same as INFCIRC/153, paragraph 34(c). Paragraphs 34(a) (exports) and 34(b) (imports) of INFCIRC/153 similarly correspond to Article 9(a) (imports) and 12(b) (exports) of pre-34(c) material in the Quad agreement. Thus, like INFCIRC/153, any imports or exports of UOC are to be reported to ABACC, but these do not require full material accountancy, and therefore neither ABACC nor the IAEA can verify Article 9(a) declarations without an additional protocol being in force.[144]

Neither Brazil nor Argentina has signed an additional protocol. Brazil claims that its memberships of the bilateral inspection aspect of ABACC and the Treaty of Tlatelolco, which established a nuclear weapons-free zone in Latin America, already provide higher levels of assurances that its nuclear activities are for peaceful purposes only. More fundamentally, Brazil has stated that it has no intention of implementing the additional protocol without significant steps in global nuclear disarmament, underlining its position in a December 2008 official defence strategy paper.[145] Argentina, on the other hand, has said little on its non-signature. Given its joint safeguards arrangements, however, it would not be able to move without Brazil.

Although neither is a party to the additional protocol, both agreed to the provisions of Policy Paper 18, including strengthening control of uranyl nitrate at their respective facilities in Cordoba and Sorocaba (São Paulo).[146] The conversion plant in Cordoba produces UO_2 via nitrate (NO_3/UO_3) from Argentinean yellowcake or impure (usually imported) U_30_8 with a design capacity of 200t/yr.[147] According to ABACC, the first inspection of material at Cordoba covered by PP18 took place in January 2013.[148] In Brazil, the navy runs pilot and testing facilities for its nuclear propulsion programme at the Aramar Experimental Center, located in Iperó, Region of Sorocaba, in the state of São Paulo. Aramar's infrastructure

[144] Discussion with ABACC officials, 25 March 2013.

[145] Mark Hibbs, 'Nuclear Suppliers Group and the IAEA Additional Protocol,' *Nuclear Energy Brief*, 18 August 2010.

[146] Without changing the interpretation of the starting point of safeguards under the legal framework of the Quadripartite Agreement between Argentina, Brazil, ABACC and the IAEA.

[147] The other plant in Argentina is located in Pilcaniyeu, Bariloche, and produces uranium hexafluoride (UF_6) starting from pure UO_2 already under safeguards. This plant is on shutdown status. See Orpet J.M. Peixoto and Hugo E. Vicens, 'Alternative Techniques when Applying Safeguards to Natural Uranium Conversion Plants,' Technical Meeting INMM (2007).

[148] Discussion with ABACC officials, 25 March 2013.

includes a partially constructed uranium conversion plant, which will produce UF_6 (via nitrate) for use in the Brazilian enrichment programme. The process route is UOC→ NO_3→ ADU→ UO_3 → UF_4 → UF_6. According to ABACC, the conversion plant at Aramar has been redesigned to allow for verification of material covered by PP18.[149] It has a designed capacity of 40t/yr. Regarding Policy Paper 21, Brazilian officials have stated that Brasilia will not stand in the way of the revised starting point.[150]

3.7 Euratom

Unlike ABACC or the IAEA, Euratom has applied reporting and inspection to the front end of the nuclear fuel cycle since the establishment of the 1957 Euratom Treaty. The application of full safeguards across Euratom states therefore begins prior to the IAEA starting point. Whereas the IAEA Statute does not interpret the terms 'source material' or 'safeguards' as applying to ore or ore residue, Euratom's control begins as soon as ore is produced domestically or material is imported into the territory of a member state. Article 77 of the Treaty states that the Commission shall satisfy itself that 'ores, source materials, or special fissile materials are not diverted from intended uses as declared.' Consequently, Euratom requires operational records to be kept for ores and source materials, including during transport, and inspectors to be given access to places and data.

In 1973, the Agreement between Euratom and the IAEA (INFCIRC/193) applied IAEA safeguards across Euratom member states (previously, Euratom states had bilateral safeguards agreements with the IAEA). The UK began applying safeguards to imports of natural and enriched uranium under this treaty on 1 January 1973.[151] The Treaty is legally binding and affects all but the smallest quantities of certain ores. Indeed, while Euratom Regulation 9 excludes uranium ores containing less than 0.1 per cent uranium, Euratom safeguards 'require that any batch of yellowcake that rounds up to one kilogram is reportable.'[152]

With the Additional Protocol in force across all Euratom states in 2004, Commission Regulation (Euratom) No. 302/2005 of 8 February 2005 on the

[149] Ibid.

[150] Discussion with Brazilian official, 24 June 2014.

[151] Molly Berkemeier et al., *Governing Uranium in the United Kingdom*, DIIS Report 2014:02, p. 26.

[152] Cindy Vestergaard, 'Starting from zero: Denmark and Greenland's uranium', *The Copenhagen Post*, 21 September 2013, http://cphpost.dk/news/opinion-starting-from-zero-denmark-and-greenlands-uranium.6947.html.

application of Euratom Safeguards stated that the basic technical characteristics of ore extraction operations should be declared, and that accounting records of ore quantities extracted with an average uranium and thorium content and of the stock of extracted ore at mines should be kept for at least five years, with annual declarations on the amount of material dispatched from each mine or exported from the state. This Regulation updated Commission Regulation (Euratom) 3227/76 of 19 October 1976 concerning application of the provisions on Euratom safeguards under Articles 78 and 79 of the Euratom Treaty. It is important to note that, under Commission Regulation (Euratom) 302/2005, natural uranium is subject to the same reporting requirements as any other nuclear material – Material Balance Report, Physical Inventory Listing, Advance Notification of Imports/Exports, and so on.[153]

The Euratom Treaty also established the European Supply Agency (ESA), which has the exclusive right to conclude contracts for the supply of ores and source materials, whether generated from inside or outside the Community. The ESA has a right of option on materials produced within the Community, meaning that it has to be given first refusal on sales of uranium before a member state can sell it to a third party. According to Commission Regulation (EURATOM) No66/2006, all transfers, exports and small quantities of ores and source materials also need to be reported to the ESA, with exemptions for quantities of not more than one tonne of uranium and thorium within a five tonnes per year limit.

3.8 Nuclear Weapons Free Zones and Uranium Supply

The international system of safeguards has been further enshrined in the world's five regional Nuclear Weapons Free Zones (NWFZs). All five zones require member states to conclude safeguards agreements with the IAEA. The Treaty of Tlatelolco is the only one where safeguards are not a condition of nuclear supply.[154] All others prohibit exports of source or fissionable material and nuclear technology to a non-nuclear weapon state unless subject to IAEA safeguards. The Semipalitinsk Treaty, establishing a NWFZ in Central Asia on 21 March 2009, goes one step further to require the conclusion of an additional protocol

[153] Molly Berkemeier et al., *Governing Uranium in the United Kingdom*, DIIS Report 2014:02, p. 26.

[154] The Treaty for the Prohibition of Nuclear Weapons in Latin America (the Tlatelolco Treaty) was opened for signature in Tlatelolco, Mexico, on 14 February 1967 and entered into force on 22 April 1968. The Tlatelolco Treaty was the first regional treaty on non-proliferation, and thus its negotiations were concluded before the NPT and INFCIRC/153 existed.

in recipient states along with a comprehensive safeguards agreement, before exports of nuclear materials and equipment can take place. Kazakhstan, however, concluded a bilateral nuclear cooperation agreement with India in April 2011 and began UOC exports a few months later, despite India not having a CSA and at the time not having ratified, only signed, an additional protocol.[155] Other members seem to have agreed with Kazakhstan that supplying uranium to India is consistent with their NWFZ obligations, given the lack of public debate or discussion on the topic within the zone. In August 2014, Uzbekistan and India concluded an agreement for 2,000 tU to be supplied to India from the state-owned Uzbek Navoi Mining & Metallurgy Combine.[156] In 2008, Tajikistan revoked a prohibition on foreign involvement in the uranium industry.[157] There have been reports that Tajikistan has allowed the Uranium Corporation of India Ltd (UCIL) to explore its uranium deposits,[158] though this proved not to be the case.[159]

According to Anthony and Grip, African countries have generally concluded that uranium supply to India would not be consistent with their Pelindaba Treaty obligations.[160] They state that, although India and Namibia signed an Agreement on Cooperation in Peaceful Uses of Nuclear Energy in 2009, the deal has yet to be ratified by Namibia.[161] However, this statement needs to be clarified. According to Namibian officials, no such agreement exists.[162] While South Africa is the only African NSG member (and it supported the NSG exemption for India), its domestic nuclear energy legislation allows source material to be supplied to nuclear weapons states on the condition that it is intended for peaceful purposes only and to a NNWS if the material will be subject to IAEA comprehensive safeguards agreements at all times. Under current official interpretation of the Nuclear Energy Act, the supply of South African uranium to India is prohibited.[163]

155 India ratified an additional protocol to its safeguards agreement to the IAEA in June 2014.

156 'India widens N-fuel base, signs up Uzbek firm for uranium supplies ' *The Indian Express*, 27 August 2014.

157 Togzhan Kassenov, 'Uranium Production and Nuclear Energy in Central Asia: Assessment of Security Challenges and Risks', *China and Eurasia Forum Quarterly,* Volume 8, No. 2 (2010) p. 226.

158 Ibid.

159 Email exchange with Indian official, 31 May 2015.

160 The African NWFZ entered into force as recently as 2009, with its verification instrument, the African Commission on Nuclear Energy (AFCONE), being established in October 2010.

161 Ian Anthony and Lina Grip, *Africa and the Global Market in Natural Uranium: From Proliferation Risk to Non-proliferation Opportunity*, SIPRI Policy Paper No. 39, November 2013, p. 12.

162 Discussion with Namibian official, 10 June 2015.

163 Ian Anthony and Lina Grip, ibid.

The South Pacific NWFZ (the Rarotonga Treaty), which includes thirteen states, including Australia, was opened for signature in 1985 and entered into force on 11 December 1986. It requires that no State Party provides source or special fissionable material unless subject to the IAEA safeguards applicable to a NNWS.[164] A decade later, on 15 December 1995, the Treaty on the Southeast Asia NWFZ (the Bangkok Treaty) was opened for signature, entering into force on 27 March 1997. It prohibits exports of source or fissionable material unless subject to IAEA safeguards, whether applicable to NNWS or NWS. This clause is interpreted as allowing an agreement with India to supply uranium subject to India's item-specific IAEA safeguards.

In addition to the five regional NWFZs, Mongolia is the only NWFZ specific to a single State.[165] Its non-nuclear weapon status was first declared in September 1992, and the 'Law of Mongolia on its Nuclear-Weapon-Free Status' entered into force on 3 February 2000.[166] The five NWS (China, France, Russia, United Kingdom and United States) signed parallel political declarations at a ceremony in New York on 17 September 2012, formally recognizing Mongolia's nuclear-weapon free status and reaffirming pledges made at the 2000 UN General Assembly to respect Mongolia's status and not to use nuclear weapons against Mongolia.[167] Mongolia's law on its NWFZ does not explicitly refer to IAEA safeguards. Article 5.1 does state that 'the use of nuclear energy and technology shall be permitted only by the State administrative authority in charge of nuclear energy and solely for peaceful purposes such as health care, mining, energy production and scientific research in accordance with the provisions of international treaties to which Mongolia is a party as well as in conformity with the norms and principles of international law.' Although there is currently no uranium mining in Mongolia, government-owned companies from Russia, China and France have been exploring for uranium, with the French-owned AREVA Group holding the largest number of permits for exploration.[168] On 16

[164] Treaty of Rarotonga, Article 4.

[165] A study conducted in 1976 in accordance with UN General Assembly Resolution 3261F in 1974 provided for the possibility of a single-State nuclear-weapon-free zone. The study concluded that 'obligations relating to the establishment of [NWFZs] may be assumed not only by groups of States, including entire continents or large geographical regions, but also by small groups of States and even individual countries.'

[166] 'Law of Mongolia on its Nuclear-Weapon-Free Status,' 3 February 2000: http://cns.miis.edu/inventory/pdfs/aptmongolia.pdf

[167] Daryl G. Kimball, 'Mongolia Recognized as Nuclear-Free Zone,' *Arms Control Today*, 2 October 2012.

[168] AREVA has been based in Mongolia since 1997 and is now represented in Ulan Bator by its wholly owned subsidiary AREVA Mongol. All of AREVA Mongol's twenty-two exploration permits are held by COGEGOBI, while the operating company AREVA Mines LLC will hold, and produce under, operating permits. See AREVA Mongol LLC: http://www.areva.com/EN/operations-586/areva-in-mongolia-a-strong-and-promising-presence.html. Accessed 15 June 2015.

July 2009, the Mongolian Parliament approved the Law on Nuclear Energy, which governs uranium extraction and the use of nuclear energy within the country. Article 37 outlines the basic requirements for exports and imports of nuclear material, such as requiring transferred material to 'be covered by international guarantee,' prior notice and consent for transfers to third countries, and stipulating that all nuclear material is used solely for peaceful purposes, with information on end-users being provided to the State Administrative Body.[169]

3.9 Nuclear Suppliers Group

A series of meetings from 1975 to 1978 by the then newly-established Nuclear Suppliers Group resulted in its first multilateral export guidelines, published by the IAEA in 1978 as INFCIRC/254 (subsequently amended). From a group of seven states, the NSG today has 49 members (including ten of the countries studied for the *Governing Uranium* project), plus the European Commission, which has observer status. Natural uranium and its related technologies for conversion were included in the 1978 trigger list, with guidance that States report UOC exports for nuclear purposes that exceed 500 kilograms and seek prior approval from the supplier state if a recipient state wants to enrich uranium beyond 20 percent. The Guidelines also called for IAEA safeguards as a precondition for supply. In 1992, the NSG adopted the Statement on Full-Scope Safeguards, requiring the application of IAEA safeguards on all source and special fissionable materials to current and future peaceful activities. A year later, the NSG endorsed IAEA safeguards as a condition of supply for nuclear transfers,[170] and in 1994 it adopted the 'Non-Proliferation Principle', whereby suppliers only transfer materials when they are satisfied that it will not contribute to the proliferation of nuclear weapons.[171] The NSG does not bar the export of UOC in small quantities or even large quantities if the supplier has reasonable assurance that the material will not be used for nuclear purposes.

As already noted, in 2008 the NSG granted India an exemption from its rules requiring a comprehensive international safeguards agreement as a condition of nuclear trade. The 2008 decision was based on a formal pledge by India stating

[169] Nuclear Energy Law 2012, unofficial translation, *Mongolian Mining Journal*: http://en.mongolianminingjournal.com/content/19681.shtml. Accessed 15 June 2015.

[170] This policy does not apply to agreements or contracts drawn up on or prior to 3 April 1992. The updated NSG Guidelines were published as IAEA document INFCIRC/254/Rev 1, Part 1 and 2.

[171] Nuclear Suppliers Group homepage, About us: http://www.nuclearsuppliersgroup.org/en/about-us. Accessed 15 May 2015.

that it would not share sensitive nuclear technology or material with others and would uphold its voluntary moratorium on nuclear testing. On 23-24 June 2011, the NSG tightened its guidelines requiring NPT membership, a comprehensive safeguards agreement and adherence to the Additional Protocol specifically for trade in enrichment and reprocessing equipment and technology.[172] The decision does not apply to source materials, but it has created tension with its guidelines, as well as with New Delhi, which seeks to join the club.

3.10 Bilateral Nuclear Cooperation Agreements

A number of countries go beyond IAEA safeguards to require additional treaty assurances regarding peaceful uses. Bilateral nuclear cooperation agreements (NCAs) are employed by countries such as Canada, Australia, and the United States, as well as by Euratom. These agreements and their implemented 'administrative arrangements' usually include the requirement of prior consent from the supplier state before the importing state reprocesses, enriches uranium beyond 20%, or transfers the material to a third country. They also include information-sharing measures to track material, essentially attaching 'flags' to the material as it moves through the fuel cycle. Australia's uranium, for example, becomes 'obligated' as it moves through the different stages of the nuclear supply chain, and Australian obligations apply to any nuclear material generated through its use. Australia also tacks on additional conditions of supply such as limiting exports to countries that are party to the NPT (recently changed for India), have a comprehensive safeguards agreement (in the case of NNWS) and an Additional Protocol, and are party to the Convention on the Physical Protection of Nuclear Materials (CPPNM).[173]

Although there is diversity among NCAs on conditions of supply and ways of exchanging information, they have evolved over time to become an established standard for ensuring that bilateral trade in nuclear materials does not violate international rules. Given that uranium is fungible, its individual atoms cannot be physically identified and tracked once they have been mixed with material from other countries. Bilateral accounting is thus based on equivalent quantities (and quality), calculated by data on fuel burn-up rates, process losses and other operating plant parameters as the uranium supplied changes chemically and physically on

[172] Nuclear Suppliers Group homepage, History: http://www.nuclearsuppliersgroup.org/en/history1. Accessed 20 May 2015.

[173] Australian Safeguards and Non-Proliferation Office, Annual Report 2012-2013, p. 35. Australia added the Additional Protocol as a condition of supply in 2005.

moving through the fuel cycle. A proportionality principle provides that, where obligated material is mixed with other nuclear material, and is processed or irradiated, a proportion of the resulting material will be regarded as obligated corresponding to the same proportion as was obligated initially. This has led to a system of multiple flagging, where, for example, when Canadian obligated material becomes enriched in the US, it also acquires a US flag, and thus subsequent use will have to meet the NCA requirements for both Canada and the US.

For NCAs with nuclear weapons states, the principle of a 'direct substitution' may also be applied. The NCAs that Canada and Australia have with China require that any uranium supplied is used peacefully and exclusively in IAEA-safeguarded facilities. Given that the uranium supplied will undergo conversion (in unsafeguarded plants) before being transferred to safeguarded facilities, the substitution principle applies: for every receipt of Australian uranium, China provides an equivalent quantity of converted natural uranium (i.e. UF_6), which will be added to the inventory of a facility designated for safeguards. According to the Australian Government, this 'will have the same effect as if the yellowcake had moved through the conversion plant, and will ensure that after receipt in China, AONM remains in a facility designated for safeguards and listed under the agreement at all times.'[174] The Canadian agreement with China differs in that the China Atomic Energy Authority (CAEA) is obligated to report Canadian UOC when it passes through the gates of one of its conversion facilities and when it leaves the plant, as well as declaring its destination.[175] The NCAs with Russia similarly state that Australian and Canadian uranium must be stored, processed and used only at facilities on the IAEA safeguards eligible list. The substitution principle is also allowed.[176]

While agreements with China and Russia for supply by Canada and Australia are recent, both have accepted bilateral reporting requirements on the supplier's flag. India, however, does not. Under India's umbrella agreement with the IAEA, India has to inform the Agency about all facilities that are holding and using imported uranium, with any imports of UOC to be notified within four weeks of arrival. If material subject to safeguards is transferred to a facility not on the list, safeguards

[174] Australian Government, Department of Foreign Affairs and Trade, Australia-China Nuclear Material Transfer Agreement and Nuclear Cooperation Agreement, November 2007: http://www.dfat.gov.au/geo/china/treaties/faq.html.

[175] Discussion with Canadian official, 3 July 2013.

[176] Anton Khlopkov and Valeriya Chekhina, *Governing Uranium in Russia*, DIIS Report 2014:19, p. 54.

must be applied to that facility. India does have a policy of requiring NCAs before nuclear trade can occur, but it rejects flagging and argues that, because all imported uranium will be used in safeguarded facilities and thus reported to the IAEA, there is no need for bilateral reporting.

The NCAs concluded with India are the weakest on tracking thus far, signalling a counterintuitive watering down of a universal industry practice for a state that is not party to the NPT. India's exemption from the NSG Guidelines extends across a number of fundamental NCA practices and permissions. Australia's agreement with India, for example, is unlike any other of its NCAs in that it does not include any provision for dealing with the consequences of non-compliance with the NCA or the IAEA, nor fallback safeguards which would be similar to IAEA safeguards should the IAEA not be able to monitor Australian material for any reason. The Australia–India agreement calls instead for undefined 'appropriate verification measures' and contains no arbitration clause.[177] The agreement also gives India advance consent to reprocess Australian uranium before the reprocessing plant has been built, and without requiring consent for downstream facilities using the separated plutonium. This provision exists in one other Australian NCA, specifically with Japan, in which Canberra gave its consent to reprocessing at the Japan Nuclear Fuel Services plant (i.e. the Rokkasho Nuclear Fuel Reprocessing Facility) and the Monju reprocessing plant.[178]

However, Australia is further bound by its *Nuclear Non-Proliferation (Safeguards) Act 1987*, which requires annual reporting by the Director General of the Australian Safeguards and Non-Proliferation Office (ASNO),[179] including information on the total quantities of Australian uranium under each agreement at each stage of the nuclear fuel cycle. For Australia to remove the bilateral tracking provision for India, it would have to amend the legislation or risk being in violation of its own statutory requirements. An amendment is not being discussed. On 12 February 2015, Dr Rob Floyd, Director General of ASNO, testified at the Joint Standing Committee on Treaties (JSCOT) that New Delhi and Canberra are currently negotiating an Administrative Agreement that 'sits with the [NCA] that would

177 Kalman A. Robertson, 'Submission to the Joint Standing Committee on Treaties Agreement between the Government of Australia and the Government of India on Cooperation in the Peaceful Uses of Nuclear Energy: Interpreting the Australia-India Nuclear Cooperation Agreement,' 27 November 2014.

178 Agreement between the Government of Australia and the Government of Japan for Co-operation in the Peaceful Uses of Nuclear Energy, Canberra, 5 March 1982. Australian Treaty Series, No. 22, 1982.

179 Specifically Section 51(2).

meet those [reporting] requirements' and that 'could be slightly different in the way it is implemented while still getting the same outcome that we need to meet the legislated requirements.'[180]

The NSG exemption for India therefore challenges long-standing NSG policies on supply and on the application of safeguards, which took nearly three decades to build up. A 2010 draft non-paper by Australia, Canada, Euratom and United States outlined the common understandings and practices the four follow with respect to the administration of obligation accounting and transfers under NCAs.[181] At the time, the United States had already concluded a framework NCA with India in October 2008, as had Canada (signed June 2010). Both were working on negotiating the Administrative Arrangements (AA) for these NCAs, and while Australian talks initially occurred with India in 2006, Canberra maintained its policy of prohibiting nuclear sales to India until 2012, when it reversed the policy and serious negotiations on a bilateral NCA began. In the non-paper, the three states plus Euratom stress that all nuclear items and material subject to NCAs should be tracked by the recipient state and inventoried, with reports generally including cumulative information on imports, exports, retransfers and other processes (such as production and loss) over a calendar year. However, the 2012 announcement by Canada that the Administrative Arrangement with New Delhi had been agreed speaks generally of 'discussions and information sharing' – it makes no reference to the inventory reports and accounting processes[182] that are included in other Canadian NCAs or listed as best practices in the non-paper.

The US–India Administrative Arrangement was finalised in February 2015. Reportedly the bilateral tracking has been weakened, although there seems to have been a breakthrough on tracking U.S.-exported materials and retransfers within India, including items sourced from third countries but processed in the United States.[183] This breakthrough was only possible because the material covered is not bulk material (i.e. not UOC). If this is indeed the case, suppliers may find it more

[180] Official Committee Hansard (JSCOT), 12 February 2015, page 3: http://parlinfo.aph.gov.au/parlInfo/download/committees/commjnt/4e154c16-3030-400c-893f-28c3701bdd90/toc_pdf/Joint%20Standing%20Committee%20on%20Treaties_2015_02_12_3186_Official.pdf;fileType=application%2Fpdf#search=%22committees/commjnt/4e154c16-3030-400c-893f-28c3701bdd90/0001%22.

[181] 'Draft Non-Paper: Document of Common Understandings and Practices regarding the Administration of Bilateral Nuclear Cooperation Agreements', Version 08/09/2010.

[182] Paul Meyer, 'India and the meltdown of Canada's nuclear non-proliferation policy', *The Star*, 15 November 2012.

[183] Brahma Chellaney, 'The U.S.-India nuclear breakthrough that wasn't', *The Japan Times*, 11 February 2015.

desirable to have the U.S. process uranium they are exporting to India. This could be done under a contractual arrangement with the recipient state for toll conversion, enrichment and fuel fabrication.

The NSG exemption thus exempts India from the NPT as well as from its own best practices, creating a fourth tier of safeguards. As noted by John Carlson, former Director General of ASNO in a statement submitted to the Australian parliament's Joint Standing Committee on Treaties (JSCOT) in September 2014:[184]

> In 2006, when discussions between Australia and India on a nuclear agreement first started, India insisted on being treated the same as Australia's other agreement partners. But now India has moved the goal posts, expecting an agreement that contains less than all other Australian partners have agreed to. Far from building confidence in its intentions, India's position has the opposite effect. [...] The fact that India wants to weaken Australia's longstanding safeguards conditions shows it is not thinking in terms of assuming the same responsibilities and practices as other leading countries – this is not an encouraging start either for this agreement or for a closer bilateral relationship.

However, bilateral safeguards and NCAs are not used by all suppliers. Some producers are content with purchase contracts, such as Kazakhstan, Malawi and Namibia, while countries such as Brazil and South Africa only use their reserves domestically and currently do not sell their UOC abroad.[185] It should also be noted that some non-producing but consuming countries do tack on 'conditions of purchase', such as Japan, where utility companies insist on uranium from Namibia because the purchase agreement is considered to be part of Japan's development assistance to Africa.[186]

As the civilian nuclear market is expanding and becoming increasingly global, the need grows for assurance that nuclear materials processed in facilities used for peaceful purposes are not diverted to military use, whether for both the NNWS and NWS. Tertrais and Padova raise the issue of whether free use will

[184] Mark Hibbs, 'India's Bilateral Obligations,' *Arms Control Wonk*, 7 February 2015.

[185] Brazil, however, does ship its yellowcake abroad for processing, it then being returned to Brazil in the form of UF_6.

[186] Ian Anthony and Lina Grip, *Africa and the Global Market in Natural Uranium: From Proliferation Risk to Non-proliferation Opportunity*, SIPRI Policy Paper No. 39, November 2013, p. 9.

be sustainable, given the creation of the triangular relationship between France, Niger and China.[187] Similarly, how to track Kazakh uranium potentially processed through a refinery jointly owned by Cameco and Kazatomprom is becoming an issue for Canada. The idea of a refinery in Kazakhstan, similar to Cameco's Blind River, is still at the design stage, but its potential requires Ottawa to include third-country reporting requirements in the Administrative Arrangement currently being negotiated.[188] Given that Kazakh material could pass through nuclear technology made in Canada, it could become 'Canadian-obligated' before heading to China. If or when the refinery is completed, a Canadian flag may then be attached to Kazakhstan's refined uranium, which would be a first for Kazakhstan.

3.11 Recommendations

1. Make clarifications to Paragraph 34(c) public

The revised definition of paragraph 34(c) creates new obligations for state regulatory authorities and facility operators. However, States, the industry and stakeholders cannot access the new definition without going to the IAEA first, which makes the process unduly bureaucratic and mysterious. PP21 does not need to be made public in its entirety, but any clarifications to paragraph 34(c), governing when full safeguards obligations under the NPT kick in, should be made widely available to the public, industry, states and stakeholders.

2. Employ bilateral nuclear cooperation agreements

Bilateral nuclear cooperation agreements provide additional treaty assurances of peaceful uses. These state-to-state agreements frame the conditions for nuclear trade and make possible bilateral reporting mechanisms, information sharing, and prior consent to the transfer, enrichment or reprocessing of the material.

[187] Bruno Tertrais and Cécile Padova, *Governing Uranium in France*, DIIS Report 2014:17, p. 43.

[188] The Kazakh-Canadian nuclear cooperation agreement entered into force in August 2014. The author understands that negotiations for an AA may have been concluded during the writing of this report. Until a public statement is made otherwise, however, the report notes that AA negotiations are underway.

4. Uranium Security

4.1 The Starting Point of Security

The nuclear security regime is governed by three international instruments: the 1987 Convention on the Physical Protection of Nuclear Material (CPPNM) and its 2005 Amendment, the 2007 International Convention on the Suppression of Acts of Nuclear Terrorism (ICSANT), and UN Security Council Resolution 1540 of 2004. These instruments recognise principles for the protection of nuclear material and identify offences that are to be punishable by national law. The IAEA also develops and publishes a *Nuclear Security Series* to assist member states in implementing a physical protection regime consistent with the obligations and commitments of the three treaties. The guidance is voluntary for a Member State to implement. Since 1972, the Agency has circulated the document *Recommendations for the Physical Protection of Nuclear Material*. In 2011, the most recent revision was published as 'Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities' NSS13 (INFCIRC/225/Rev.5).

The provisions in all these instruments apply to uranium ore concentrates (UOC). ICSANT's definition of nuclear material includes 'uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue' [189] which could be used for developing nuclear weapons, while UN Security Council Resolution 1540 binds all UN member states to implement 'appropriate' and 'effective' accountancy and physical protection measures over 'materials [...] covered by the relevant multilateral treaties and arrangements, or included on national control lists'. [190] The CPPNM and INCIRC/225 state that natural uranium should be protected in accordance with 'prudent management practice', though none of these instruments describe specific measures that could be considered 'appropriate', 'effective' or 'prudent'.

Moreover, all of these instruments encourage, but do not formalise, the exchange of information among States Parties and international organisations. Unlike safeguards where reporting and verification build confidence in NPT compliance, the responsibility for nuclear security is considered a matter of national sovereignty

[189] Article 1, Paragraph 2, International Convention on the Suppression of Acts of Nuclear Terrorism, New York 13 April 2005.

[190] Resolution 1540 (2004) Adopted by the Security Council at its 4956th meeting, on 28 April 2004. S/RES/1540 (2004).

and there is thus no international oversight. The CPPNM and ICSANT have provisions for developing guidance and for exchanging information, but the mandates and incentives are weak. UNSCR1540 does obligate regular reporting from countries on how they prevent the spread of weapons and materials of mass destruction and their delivery systems, but compliance is uneven, as is the quality.

Two treaties establishing nuclear weapons free zones make specific reference to the CPPNM. In Article 10 of the Treaty of Pelindaba, each party undertakes 'to apply measures of physical protection equivalent to those provided for the in the Convention on the Physical Protection of Nuclear Material and in recommendations and guidelines developed by IAEA for that purpose'[191] Article 9 of the Treaty of Semipalatinsk requires parties to 'apply measures of physical protection to nuclear material in domestic use, transport and storage, to nuclear material in international transport and to nuclear facilities within [their] territory at least as effective as those called for by the [CPPNM]', along with IAEA recommendations and guidelines. The Treaty of Bangkok (Article 4(2)(c)) requires the sharing of information related to national security when requested by another State Party. The Treaty of Tlatelolco and the Treaty of Rarotonga do not spell out specific nuclear security measures.

In 2012, the IAEA's Division of Nuclear Security established a panel of consultants to draw up technical guidance entitled 'Nuclear Security in the Uranium Industry' to identify practical and implementable nuclear security measures that are considered prudent in the production, storage and transport of UOC. This guidance is voluntary and is intended to fill a gap with respect to UOC for States, regulatory bodies and industry to prevent the unauthorised removal of UOC as part of a complete physical protection regime. Notably, while for safeguards purposes the IAEA has determined the timeliness goal for the detection of a significant quantity of natural uranium (ten metric tonnes of uranium or twelves tonnes equivalent U_3O_8) in one year, the technical guidance considers it prudent for nuclear security purposes to detect the unauthorised removal of a quantity of UOC equivalent to a single drum over a one-month period.[192] The document notes that security measures based on risk assessments and a graded approach should begin when uranium is being or has been concentrated, purified

[191] Ian Anthony and Lina Grip, *Africa and the Global Market in Natural Uranium: From Proliferation Risk to Non-proliferation Opportunity*, SIPRI Policy Paper 39, November 2013, p. 41.

[192] Nuclear Security in the Uranium Industry, IAEA Technical Guidance, Draft IAEA Nuclear Security Series, December 2014.

and transported.[193] Consequently, the starting point for nuclear security begins earlier in the nuclear supply chain than it does for international safeguards.

4.2 The Risk

Uranium contained in ore and in the majority of the milling, extraction and concentration process is low risk and is usually (and effectively) protected using current industry best practice. The biggest barrier to stealing ore is to do so without detection, given that the quantities are so large. Given that dump trucks transporting ore typically have a 20-30 tonne capacity (dependent upon the addition of a trailer), it could require anywhere from 10 to 100 trucks' worth of material to make such an endeavour worthwhile. Even assuming high-grade uranium at the site, it is extremely unlikely that such an operation could happen without being noticed.[194] Nonetheless this has not stopped attempts to steal ore, as witnessed in Brazil in 2004, when police seized 1,320 pounds of ore in a pick-up truck close to the Caetité mine,[195] or in Namibia, when 324kg of uranium ore was stolen from the not-yet operational Trekkopje Mine in August 2011.[196]

The material becomes more attractive as the concentration of uranium increases during processing and becomes potentially more vulnerable when it reaches concentrated form. As noted in the IAEA technical guidance, UOC within the extraction and concentration process up to the point of precipitation can be adequately protected using standard industrial-security measures. UOC that has been precipitated and is being or has been concentrated, purified and transported needs additional security measures to address the extra risks involved.

The most obvious risk is theft or the unauthorised removal of UOC from the mine or mill or during transport and storage by outsiders, insiders or a combination of the two. The insider/outsider risk was demonstrated in September 2009 when two employees of the Rössing Uranium Mine in Namibia and a member of the Namibian Defence Forces were arrested trying to sell 170 kg of natural uranium

193 Including the process of concentrating the uranium into intermediate forms of UOC, including ammonium diuranate (ADU), sodium diuranate, and their refining into uranium trioxide (UO_3), uranium peroxide (UO_4) and triuranium octoxide (U_3O_8).

194 Sharon Squassoni et al., *Governing Uranium in the United States*, p. 30.

195 'Brazil police seize black market uranium ore,' Reuters, 25 August 2004: http://forests.org/shared/reader/welcome.aspx?linkid=34512&keybold=nuclear%20AND%20%20uranium.

196 http://www.nti.org/analysis/articles/700-pounds-uranium-ore-stolen-areva-mine-namibia-four-suspects-arrested-material/.

concentrate to an undercover police agent. Namibian police initiated the illicit purchase and targeted Rössing employees, offering large amounts of money (reportedly several thousands of dollars per kilogram) with the goal of determining whether yellowcake could be smuggled out of the mine.[197]

From January 1993 to December 2012, a total of 2,331 incidents were reported to the IAEA's Incident and Trafficking Database (ITDB) by participating States and some non-participating States.[198] Of the 2,331 confirmed incidents related to nuclear material, 419 involved unauthorised possession and related criminal activities. Incidents included in this category involved illegal possession, movement, and attempts to trade in or use nuclear material or radioactive sources illegally. Information on natural uranium is minimal, but a paper by Rukhlo and Gregoric dated 2008 noted that there had been a total of 91 incidents between 1993 and 2007 involving the illicit trafficking of natural uranium.[199]

There is also a risk of diversion from approved routes and end-users after UOC has been exported from a supplying state. The most famous is the Plumbat Affair of 1968, when two hundred tonnes of yellowcake was diverted in Antwerp from its declared destination in Italy to Haifa, Israel, and then to Dimona. The incident happened before the NPT was in force, although Euratom safeguards did apply. At the time, the then decade-old organization was in a state of disorganisation, with member states disagreeing on a range of issues, from reactor technologies and research funding to the pace of European integration. Euratom was also in the process of moving offices and files from Brussels to Luxembourg. It took the organisation upwards of seven months to confirm that the uranium had gone astray.[200] Today, given that UOC is exempt from full material accountancy and control, there is a risk that a group of individuals might store UOC until an opportunity arises to sell it on the black market to a state that has the technical means to process, purify and convert the UOC. The risk of such a scenario increases if inventory and accountancy management and tracking procedures are poor and the facility is located in a state that has limited regulatory oversight.

[197] 'Namibia's Rossing Uranium – A USG Evaluation,' *The Telegraph*, 1 February 2011. http://www.telegraph.co.uk/news/wikileaks-files/nuclear-wikileaks/8297092/Namibias-Rossing-Uranium-A-USG-Evaluation.html.

[198] IAEA website, 'Nuclear Safety and Security': http://www-ns.iaea.org/security/itdb.asp.

[199] Rukhlo, V. and M. Gregoric, 'Uranium production: best practice of nuclear security measures', paper presented at IAEA Technical Meeting on Implementation of the Sustainable Best Practice in Uranium Mining and Processing, 15-17 October 2008, IAEA, Vienna.

[200] For a full account see Elain Davenport, Paul Eddy, Peter Gillman, *The Plumbat Affair* (B. Lippinoctt Company), 1978.

In the more recent past, there have been incidents of uranium smuggling in Africa, where the production of uranium from illegal mining and milling operations is also a risk. According to a report by Broodryk and Stott, twelve incidents occurred in Africa between 1994 and 2005, plus four incidents in Tanzania and two incidents each in the Democratic Republic of Congo (DRC), Kenya, Namibia and South Africa. Most of these incidents involved stolen uranium ore, usually stored in containers from unidentified sources. The authors stress that the deterioration of security around mining sites in the DRC represents the most pressing nuclear security challenge in Africa, where illegal uranium and cobalt mining at the Shinkolobwe mine has been of particular concern.[201] In November 2010, the UN released a report confirming that a group of Rwandan-led Hutu rebels in the east of the DRC attempted to sell six containers of yellowcake produced at the Shinkolobwe mine during the days of Belgian colonial rule, but could not find a buyer and after more than a year gave up.[202] A month later, the US and DRC signed an agreement to prevent the trafficking of nuclear and radioactive materials.[203]

In a recent case from August 2013, a man was arrested at JFK International Airport with alleged yellowcake samples hidden in his shoes in his luggage.[204] He had responded to an advertisement in May 2012 posted on the website Alibaba.com by an undercover US agent for the purchase of uranium. He claimed to have sourced the substance from Sierra Leone and was expecting to meet a contact in Miami for onward sale of 1,000 tU, which was reportedly to be sent to Iran.[205] During court proceedings the following May, it was revealed that the material in his shoes was dirt containing 33 ppmU, typical for soil from Sierra Leone.[206] The jury handed down a verdict of 'not guilty'. As with the undercover operation at Rössing, the operation by Homeland Security again raises the question of whether such operations catch smugglers or create them.[207]

201 Amelia Broodryk and Noel Stott, 'Securing Africa's Resources,' 15 February 2011: http://www.issafrica.org/iss-today/securing-africas-nuclear-resources. Accessed 27 May 2015.

202 UN release Nov. 29, 2010.

203 UN Security Council Report S/2010/596, 29 November 2010.

204 'Man arriving at JFK accused for trying to export uranium to Iran,' *New York Times*, 23 August 2013: http://www.nytimes.com/2013/08/24/nyregion/man-arriving-at-jfk-is-accused-of-trying-to-export-uranium-to-iran.html.

205 'U.S. arrests man from Sierra Leone in Iran uranium sting,' Reuters, 22 August 2013: http://www.reuters.com/article/2013/08/23/us-usa-florida-uranium-iran-idUSBRE97M01Y20130823.

206 Stuart A. Reed, 'The Uranium Sting: Did Homeland Security Catch a Smuggler or Create One?', Bloomberg Business, 11 September 2014: http://www.bloomberg.com/bw/articles/2014-09-11/uranium-sting-homeland-security-caught-smuggler-or-created-one.

207 Ibid.

Another pressing nuclear security challenge in Africa is the 6,400 containers of yellowcake stored close to Sabha, Libya. Libya admitted to the IAEA in 2004 that it had imported 2.263 metric tonnes of Niger UOC from 1978 to 1981, but only declared the import of 1,000 tU. At the time, Libya was not required to report UOC imports, this not changing until July 1980, when its Safeguards Agreement with the IAEA entered into force.[208] The remaining 1,263 tU were thus not subject to IAEA safeguards.[209] The acquisition was part of Qaddafi's pursuit of nuclear weapons, which began in the late 1970s and continued until the end of 2003.[210] In 2004, IAEA inspectors verified the UOC and confirmed the contents and quantity of material contained in the drums, which were consistent with Libya's declaration.[211] Although the last of Libya's enriched uranium was removed in 2009, the stockpiles of yellowcake remain in the country, raising further concerns about the security of the stockpile as the situation in the country deteriorates and militants associated with the Islamic State are joining rival groups in fighting for control. The IAEA has stated that it 'has tentatively scheduled safeguard activities at this location once the situation in the country stabilises'.[212]

Lastly, there is the risk of sabotage. The IAEA defines sabotage as 'any deliberate act directed against a nuclear facility or nuclear material in use, storage, or transport which could directly or indirectly endanger the health and safety of personnel, the public or the environment by exposure to radiation or release of radioactive substances'.[213] AREVA considers UOC to be a high-value target, and in the case of Niger, for example, requires assistance from the government to guard the mine and escort the UOC convoy. Despite these security measures, the risk of sabotage or attack was underscored on 23 May 2013 when coordinated car bombings thirty minutes and 250 km apart targeted the military barracks in Agadez and the Somair uranium mine in Niger. The attacks partially shut down the mine for over two months, with full operations not resuming until early August 2013. Its suspension

[208] IAEA Report to the Board of Governors, 'Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya,' GOV/2004/33, 28 May 2004, p. 6.

[209] Libya country profile, Nuclear Threat Initiative: http://www.nti.org/country-profiles/libya/nuclear/. Accessed 18 June 2015.

[210] IAEA Report to the Board of Governors, 'Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya,' GOV/2004/33, 28 May 2004, p. 3.

[211] IAEA Report to the Board of Governors, 'Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya,' GOV/2008/39, 12 September 2008, p. 9.

[212] 'Dumped in the desert ... Gaddafi's yellowcake stockpile,' *The Telegraph*, 25 September 2011.

[213] IAEA, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Revision5), IAEA Nuclear Security Series No. 13, IAEA, Vienna, 2011.

cost Areva an estimated 18 billion CFA francs (US$36.8 million) a month.[214] The militants stated that their targets were Niger and France because of their cooperation in combating insurgents in neighbouring Mali. The security environment in Niger has also had an impact on the CNNC's Azelik uranium mine, which was closed down for months after the attacks.[215] The risk of sabotage therefore may not be done expressly for uranium acquisition, with the threat spreading to all foreign-owned enterprises within a country, but uranium sabotage comes with its own risk given its radioactive properties and its high value within the nuclear supply chain.

4.3 Physical Protection

The CPPNM imposes specific requirements regarding the transport of natural uranium. Annex 1 of the Convention states that, 'for natural uranium other than in the form of ore or ore-residue, transportation protection for quantities exceeding 500 kilograms uranium shall include advance notification of shipment specifying mode of transport, expected time of arrival and confirmation of receipt of shipment'.[216] To this end, the CPPNM enshrined the minimum 500 kg limit listed in the 1978 Guidelines of the Nuclear Suppliers Group (NSG).[217] However, the CPPNM is specific to international transport. As of 19 January 2015, 152 states have joined the Convention, with forty-four signatories. All fifteen states studied under the *Governing Uranium* project are States Parties to the CPPNM. Indeed, it is the only treaty common to all.

In 2005 the CPPNM was amended to extend its provisions to the protection of nuclear material and facilities in domestic use, storage and transport against theft and sabotage. It would also expand cooperation between and among states regarding rapid measures to locate and recover stolen or smuggled nuclear material, mitigate any radiological consequences of sabotage, and prevent and combat related offences. The amendment will enter into force when two-thirds of States Parties have ratified it. As of 8 July 2015, 57 per cent (86 out of 152 states parties) have ratified the amendment.[218] Major uranium producers such as Australia, Canada and Kazakhstan are parties and apply the CPPNM's provisions domestically. The same

[214] 'Areva's Niger mine back at full production after Islamist attack,' *Reuters*, 7 August, 2013.

[215] Discussion with a representative of the uranium industry, 12 October 2013.

[216] The Convention on the Physical Protection of Nuclear Material, Annex 1, paragraph 2.

[217] Which were published as INFCIRC/254 in February 1978.

[218] See Amendment Status, IAEA: https://www.iaea.org/Publications/Documents/Conventions/cppnm.html. (Accessed 16 May 2015).

goes for China, France, India, Russia and the United Kingdom. Others studied have yet to ratify: Brazil, Malawi, Namibia, Pakistan, South Africa, Tanzania and the United States. However, the United States is in the final stages of ratifying the CPPNM, with President Obama signing the USA Freedom Act on 4 June 2015, which includes language to implement the 2005 CPPNM Amendment and ICSANT.[219] The Department of State is preparing the instruments of ratification to the depositaries.[220]

Given that the responsibility for nuclear security functions without international oversight and is considered a matter of national sovereignty, the application of the CPPNM (and Amendment) obligations varies widely across states. Looking across major suppliers, physical protection measures generally include access controls through entry checkpoints, fences,[221] communications at all levels of security personnel, and surveillance. Most of the measures have been self-imposed by industry out of commercial interest. In the United States, for example, where there are no specific physical protection requirements for uranium recovery facilities, uranium producers tend to use armed guards at their mills, including 24-hour surveillance and barbed wire fences, although this is not universal, especially at ISL facilities.[222] Although the Department of Transport does not typically include security as a guidance metric, this may change with the ratification of the CPPNM currently underway in the United States.

The experience is somewhat similar in Canada in that the Canadian Nuclear Safety Commission (CNSC) does not prescribe security regulations specific to natural uranium under the Nuclear Security Regulations.[223] It does state in a footnote that 'any quantities of natural uranium, depleted uranium and thorium should be protected at least in accordance with prudent security practice'.[224] Information on nuclear security, for example, is required in license applications for uranium mines and mills in the newly updated 'Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills' issued in April 2015, though the specific information

[219] 'Passage of Implementing Legislation for Nuclear Security Treaties', John Kerry, Secretary of State, Press Statement, 4 June 2015.

[220] To the IAEA Director General with regard to the CPPNM Amendment, and to the Secretary General of the UN with regard to ICSANT.

[221] Some countries such as Canada do not allow perimeter fencing due to aboriginal land and hunting rights.

[222] Sharon Squassoni et al., *Governing Uranium in the United States*, p. 38.

[223] Nuclear Security Regulations *SOR/2000-209*, last amended 13 March 2015.

[224] CNSC, 'Information Dissemination: Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills,' REGDOC-3.5.1, April 2015, p. 46.

that needs to be provided is not clarified. Under the Nuclear Safety and Control Act, licensees are required to 'make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations'.[225] All mill operators do have their own security plans in place, including procedures for emergency response.[226] Uranium prior to the point of conversion also does not fall under the requirements set out in the UK's nuclear security regulations.[227]

In Kazakhstan, the Law of the Republic of Kazakhstan 'On Licensing', ST NAK 13.1-2010, sets out the State standard, which establishes technical requirements for safety systems equipment, engineering and the technical strengthening of strategic and critical public facilities, including the physical protection of nuclear material and nuclear facilities. As a Category B material, companies must ensure against a breach of integrity which can lead to considerable material and financial damage to the state. China requires natural uranium in large quantities (in excess of 10,000 kg) to be stored in a controlled personnel access site.[228] India's nuclear security framework requires that the main plant boundary must have measures such as watchtowers, patrolable roads and radiation monitors. Security agencies also have to undertake routine surveillance of nuclear facilities (including mines).[229] Physical protection measures at the Caetité uranium mine in Brazil include a resident inspector from Brazil's National Nuclear Energy Commission (*Comissão Nacional de Energia Nuclear* or CNEN), who monitors material accountancy and physical protection. Inspections on site include counting drums and verifying the weighing of precipitate in drums. CNEN also conducts physical security inspections in the port of Salvador. To this end, even though Brazil is not a party to the CCPNM's amendment, it does implement physical protection measures on UOC domestically. Notably, legislation applicable to nuclear materials in Brazil begins when uranium is in precipitation, that is, within process at the Caetité Mining & Ore Plant.[230]

In Australia, standards are set in permits (rather than regulations) to provide flexible and tailored security requirements in line with legislative and policy changes. Australia's performance-based approach accommodates changes in operational

225 Nuclear Safety and Control Act, S.C. 1997, c. 9, current to 9 June 2015.
226 Discussion with CNSC official, 3 July 2013.
227 *Governing Uranium in the United Kingdom,* DIIS Report 2014:02, p. 32.
228 Patton, *Governing Uranium in China*, pp. 43-44.
229 Rajiv Nayan, *Governing Uranium in India*, pp. 50-51.
230 Discussion with CNEN and INB officials, March 2013.

requirements and arrives at security standards through a consultative rather than prescriptive process. In general, two layers of security are applied at mines, one in the drums and packing area, with authorised access controls and cameras installed, and the other involving dual communications systems on approved transport routes. The Australian Safeguards and Nonproliferation Office (ASNO) also requires (and approves) security plans for mines (and transport) every five years.[231] Brazil's CNEN also requires threat assessments and their re-evaluation every two years for all nuclear facilities, including mining and processing facilities.[232]

The employment of threat, risk and vulnerability assessments identifies the level of protection required and forms the basis for implementing security measures. These assessments should assess the potential threats to UOC in use, storage and transport, as well as associated sensitive information for both insider and outsider threats. The risks associated with each threat are then estimated with reference to the likelihood of the threat occurring, and vulnerabilities and measures to mitigate them are identified. With assessments in hand, a graded approach can be applied that takes into account current (and ongoing) evaluations of threat and the potential consequences should uranium be lost from custody.[233]

Discussions with industry representatives and visits to mines and mills confirm that companies routinely conduct risk assessments. Countries also review national threat assessments on a regular basis and in response to specific security events, such as the attacks in the United States on 11 September 2001.[234] Industry risk and emergency response assessments are usually widely available to national authorities, whether required by law or not. When industry representatives were asked if regulatory bodies provided threat-based information to operators, the answer was mixed. Some countries are better than others in sharing changes to threat levels. Subsequently, this is an area where regulators can work more closely with industry, both long-time producers and newcomers. Providing threat-based information to

[231] Discussion with ASNO official, 18 June 2013.

[232] Discussions with CNEN and INB officials, March 2013.

[233] See the IAEA Technical Guidance for an in-depth overview of prudent management practices associated with risk, threat and vulnerability assessments. See Appendix 6 for elements to be included in assessments.

[234] Post-9/11, the US NRC conducted a risk-based review of the entire regulatory system. Updates included certain inventory requirements for facilities that handled nuclear materials, but they did not apply to mines, mills or conversion plants. Increased site security was ordered at conversion facilities. At the time the *Governing Uranium in the United States* report was published, these new regulations were still being finalised, as the priority in making improvements fell mostly on power reactors. See *Governing Uranium in the United* States, p. 38. Similarly in Canada, post-9/11 threat assessments were updated by the CNSC, and orders were issued to nuclear power plant operators to review and upgrade their systems. Discussion with CNSC official, 3 July 2013.

the operator is vital for them to design and implement appropriate security systems. More routine interaction between industry and governments encourages a nuclear security dialogue across stakeholders and benefits producers, particularly in regions with heightened security environments. This dialogue would also assist in shaping a nuclear security culture across a state's entire nuclear fuel cycle.

Discussions with industry have also come to demonstrate how some companies are emphasising security measures and their implementation. Further to the incident in Trekoppje in 2011, for example, AREVA used the IAEA technical guidance and customised it to build its own Directive for the protection of uranium. This directive, issued in May 2014, is a supplement to the protection policy of the AREVA Group and describes the management rules for the protection of the finished product of every mining site within the AREVA group. It specifies the measures to be implemented for the protection of finished product at sites after drumming. Local legislation is also implemented in accordance with binding statutory measures in the countries that AREVA works.[235] The 2014 directive underscores how a company can go 'beyond compliance' to instil company-wide security measures and a nuclear security culture across all its front-end activities.

3S Interface

The evolution of safety and security regulations encompasses security in the strict sense (protecting nuclear materials from people) and safety (protecting people from nuclear material). As noted in the France country report, 'what is defined as nuclear "security" in 1998 is much more related to what is known today as 'safety'.[236] Nuclear security in France has come to include measures taken to ensure the protection of people and goods against threats of damage (whether natural or artificial) that can lead to shutdowns of nuclear facilities or impact material in use, storage and transport.[237] India's nuclear safety and security interface has also been synergised. Section 4 of India's Code for Radiological Safety in Uranium Mining and Milling has an explicit provision entitled 'Nuclear Security'. This section asks the authority concerned to make an assessment of '(a) Impact of site and surroundings on nuclear security and (b) Physical protection system, physical barrier, communication etc.'[238] Integrating the'3S' (safety, security and safeguards) where possible strengthens

[235] Presentation by AREVA, IAEA Regional Workshop on Security in Practice for the Uranium Ore Concentrate Industry, including during Transport, Livingstone, Zambia, 8-12 June 2015.

[236] Bruno Tertrais and Padova, *Governing Uranium in France*, p. 25.

[237] Ibid.

[238] Rajiv Nayan, *Governing Uranium in India*, p. 51.

and coordinates national (and commercial) governance when measures for one can be used to support measures for another. For example, radiological surveys of equipment and personnel exiting the facility assist in monitoring and limiting the spread of contamination and can be used to support supplementary measures under a an elevated threat environment or during a security event. Verification of locks and seals similarly protect against spills and leakage while also reinforcing barriers to unauthorised access. Licenses for security may be separate or combined with licenses issued for safety and environmental protection. Inventory controls contribute to an effectively implemented safeguards system.

4.4 Transport Security

Given that the majority of the world's uranium passes through five countries (Canada, China, France, Russia and the United States), UOC transport can involve lengthy transits from mine sites to conversion. A drum leaving a mill in Australia can travel 5,000 km to China, or upwards of 20,000 km to conversion facilities in Illinois in the United States or Ontario in Canada. In Africa, part of the Trans-Sahara Highway is dubbed the 'Uranium Highway', since it was constructed in the 1970s especially for transporting uranium from the Arlit mine in Niger to the Benin border. After traveling 1,600 km through Niger by truck to Parakou in Benin, drums are loaded on to trains, which travel another 400 km to the port of Cotonou, from where they are shipped a further 4,500 km to Le Havre in France and then transferred by rail to the Malvesi conversion facility in the south of France.[239] Africa's longest and newest uranium transport route runs from the Kayelekera mine in Malawi and passes 3,500 km through Malawi, Zambia and Namibia to Walvis Bay.

Radioactive materials (Class 7) are classified as 'dangerous goods', with most transport requirements for source material arising from safety considerations. Natural uranium (ore, UOC and unenriched uranium hexafluoride) is classified as Low Specific Activity-1 (LSA-1) material. LSA-1 materials require an Industrial Packaging (IP-1) standard quality container, which is the least rigorous of the industrial packaging classifications. This is because, even in the event of a spill, the amount of natural uranium that must be ingested to produce a significant radiation dose is significantly greater than uranium in other forms. Materials

[239] Governing Uranium website, 'Pit to Port', Country Transport Examples: http://uranium.csis.org/pit_to_port/. Accessed 15 May 2015.

are packaged and transported in such a way as to avoid contamination that may result from accidents, leaks or spills. This is consistent with IAEA industrial package requirements for LSA material.[240] All the countries the project studied harmonise with IAEA guidelines for the transport of uranium in its various forms.

For maritime transport, the provisions of the ISPS Code and the International Maritime Dangerous Goods (IMDG) Code as required by the Convention for the Safety of Life at Sea, SOLAS 74 amended, apply. These guidelines are widely adopted across states. In Russia, the Cabinet of Ministers' Resolution No. 458 of 19 July 2007 is the key document that regulates the physical protection of nuclear materials, equipment and storage facilities in Russia, including the transport of natural uranium. It is based largely on the CPPNM. Another important document is that entitled 'Safety and Security Procedures during the Transportation of Radioactive Materials' (NP-053-04), based on IAEA recommendations and guidelines for the transport of hazardous cargoes issued by the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO).[241] Table 5 is a full list of regulations for modes of transport of radioactive material.

Physical protection practices during transportation tend to be more rigorous than those at mill sites given the significant distances that have to be travelled; the number of transfers of authority a container goes through, often across several borders, requires multiple approvals in multiple jurisdictions. On land, trucks and railroad cars are generally used to transfer low-concentration solutions and slurry from satellite locations to primary processing facilities. These vehicles may be targets for theft or diversion, but the attractiveness and quantity of the uranium capable of being misused is very low. The final product, the ore concentrate, is packaged in 200 litre drums (400 kg) or four-ton hoppers and typically loaded into approved cargo containers and then transported from the concentration plant to conversion plants by ship, rail or truck. These containers are often transferred to seaports and placed in warehouses at interim storage locations. A container carries around 20-35 drums, or approximately 1-1.5 significant quantities.

[240] 'Regulations for the Safe Transport of Radioactive Material, 2005 Edition, Requirements and Controls for Transport, Table 4, Industrial Package Requirements for LSA Material and SCO,' International Atomic Energy Agency, p. 55.
[241] *Governing Uranium in Russia*, p. 43.

Table 5. Regulations for the Transport of Radioactive Material

Mode of Transport	*International / Regional Organisation*	*Name of Regulation / Agreement / Code*	*Scope*
All	IAEA	Regulations for the Safe Transport of radioactive Material SSR-6	Worldwide
All	UN	Recommendations on the Transport of Dangerous Goods	Worldwide
Sea	IMO	International Maritime Dangerous Goods Code (IMDG Code)	Worldwide
Sea	IMO	International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code)	Worldwide
Air	ICAO	Technical Instructions for the Safe Transport of Dangerous Goods by Air (TI)	Worldwide
Air	IATA	Dangerous Goods Regulations (DGR)	Worldwide
Road	UN / ECE	European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)	Regional
Road and rail	MERCOSUR / MERCOSUL	Agreement of Partial Reach to Facilitate the Transport of Dangerous Goods	Regional
Inland waterways	UN / ECE & CCNR	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)	Regional
Post	UPU	Universal Postal Convention and its detailed regulations	Worldwide

Source: World Nuclear Transport Institute

Transporters take precautions to ensure the timely delivery of uranium, which can include designated routes with designated rest stops, additional drivers, and GPS tracking of trucks to monitor engine conditions and speeds. The fitting of container bolt seals to shipping containers or dry van trailers assists in detecting tampering with cargo containers during intermediate or long-term storage, a technique used for many high-value cargoes. However, tracking is not necessarily done for the trailer, leaving open the possibility that trailers may be switched between cabs. Minimum transport security measures include storage separate from other cargo, the use and tracking of tamper-indicating devices for containers, the verification of container weight, and administrative controls to investigate and resolve indications of unauthorised removal of UOC.

Given that all states studied under the project are a party to the CPPNM, the latter's requirement to give advance notification of shipments, specifying mode of transport and expected time of arrival and confirmation of receipt of UOC (and verification of container numbers), is generally implemented across supplying and receiving states. Some producers, particularly in Africa, are experiencing heightened security environments where the risk of sabotage and unauthorised acquisition require increased protection, inspection and enforcement. In such cases, some companies and countries require UOC to travel in secure convoys, either with the military, as in the case of Niger and Benin, or using trained federal, regional or local police, as in the case of Brazil.

Security plans for transport vary across the states studied. In Australia, transport and contingency plans are required where police along the transport route are informed in advance and drivers are not allowed to deviate from the route (or contingency plan). The ports of Adelaide and Darwin have secure storage areas for UOC and every UOC shipment approved by ASNO. ASNO also certifies the use of seals.[242] While ASNO requires and approves transport security plans, the states have authority over roads and police along the route. Australian policy also requires that Australian obligated nuclear material (AONM) transhipped through third states is protected, specifically requiring that AONM transits through states that have adopted the CPPNM and Additional Protocol.[243] In the United States, shippers are required to have a security plan, but the plan does not need approval by the Department of Transportation. The security plan only applies to quantities

[242] Discussion with ASNO official 18 June 2013.
[243] Ibid.

of uranium hexafluoride that require placarding, not to U_3O_8 or ore.[244] In Canada, transport security plans are not required for UOC, but transporters use GPS tracking and have two-driver rules. In Kazakhstan, transport and security plans must be submitted to *Atomnaya Promyshlennost Kazahkstana* (Kazatomprom) two weeks in advance of transport.

In general, only a small number of transport companies are authorised to organise carriage through or in each country, usually only between one and three companies. These authorised transporters may then either carry out the transport themselves, using their own means of transport and own personnel, and/or subcontract carriage to other modal carriers (road, rail, sea or air). These subcontracted carriers may or may not be referenced in the transporter's authorisation, but they must formally undertake to comply with security and other requirements, and must be in possession of all the relevant and appropriate security instruction and transport information required to perform the carriage, as provided by the authorised transporter. Some of the major companies have their own transport or logistics subsidiaries. AREVA TN, for example, organises the majority of AREVA nuclear materials transport globally, at all stages of the nuclear fuel cycle. They also have a dedicated transportation oversight department, which secures and monitors all AREVA group transports from preparation stage to delivery, including the provision of transport risk analysis and crisis management, constant regulatory watch and qualified logistics.[245] In China, the CNNC's China Nuclear Energy Industry Corporation (CNEIC) and CGN Fuel Co Ltd (CGN-NFC) are the key transportation entities for both domestic and overseas movements, although most of the manual labour is also contracted out to various subcontractors.[246] Transporters such as AREVA transfer UOC at the border to the CNEIC or CGN-NFC (or their subcontractors).

In Malawi, the Geological Survey Department inspects the consignment before it is weighed and loaded into vehicles. This is done solely for royalty calculations. Additionally, the radiation protection authority is required to check the radiation level both before and after loading. However, this procedure is undermined by limited human resources and/or financial constraints.[247] The Geological Survey,

[244] Code of Federal Regulations, Transportation, 49, sec. 172.800(b)(14).

[245] AREVA TN website: http://us.areva.com/EN/home-2283/areva-inc-tn-logistics.html#tab=tab3. Accessed 2 June 2015.

[246] Tamara Patton Schell, *Governing Uranium in China*, p. 54.

[247] Discussion with Malawian officials, 14 October 2014.

Department of Mines, Policy, Immigration and Transit countries are notified as the material moves from the mine to the border. In Zambia, Malawi's UOC continues along approved routes (origin, storage and destination) and is accompanied by the Zambia Police Service and officers from the Ministry of Defence, the Ministry of Mines and Minerals Development and the Zambia Environmental Management Agency Radiation Protection Authority.[248] In Namibia another convoy takes over until Walvis Bay.[249] While all three countries coordinate UOC shipments, there is a need for a greater harmonisation of regulations across the three, given differing national security levels during UOC transport in each. Memorandums of understanding between the agencies involved would help, as would sharing threat assessments and streamlining the requirements for escort vehicles.

The Port of Walvis Bay is also undergoing rapid expansion and increasingly becoming a central transport hub on the southwest African coast. The development has stretched the capacity of the harbour and road infrastructure across Namibia. All new uranium projects therefore have to invest in heavy load tar roads. Currently only the Rössing mine is connected to the railway through Swakopmund to Walvis Bay, but the construction of new railway lines is being discussed.[250] The newly opened Husab mine, claimed to be the third largest uranium-only deposit, with reserves of about 140,000 tU, will add more volumes to Namibia's port. Majority owned by China General Nuclear Power Corporation (CGN), Husab is expected to operate for twenty years. In October 2014, a permanent 22-km road was opened, linking the Husab mine to the Namibian road network leading to Swakopmund, including a 160-metre bridge over the Khan River, the longest bridge to be built in Namibia since the country's independence in 1990.[251] Tanzania is also considering adding Class 7 materials through its port of Dar es Salaam, a route that would greatly reduce transportation costs and transits from uranium mines in Malawi and Tanzania to the port.

Many transit countries along uranium shipping routes also have their own rules, such as Auckland, where New Zealand law allows ships carrying radioactive materials into port, but does not permit the transfer of nuclear materials to

[248] Discussion with Zambian official, 15 October 2014.

[249] Discussion with Zambian official, 15 October 2014.

[250] *Uranium Past and Future Challenges: Proceedings of the 7th International Conference on Uranium Mining and Hydrogeology*, Broder J. Merkel and Alireza Arab eds., Springer International 2015.

[251] Swakop Uranium, Africa Outlook, 31 October 2014: http://www.africaoutlookmag.com/outlook-features/swakop-uranium957. Accessed 28 May 2015.

another ship in the port.[252] There is a concern that shipments of yellowcake are sometimes denied or delayed by carriers and ports. Work has been done by various fora to address these issues, recognising the need to improve the streamlining and harmonisation of approval processes and dealing with shipment denials. The World Nuclear Transport Institute (WNTI) stresses that the incorrect use of package marks and labelling and the failure to complete dangerous goods forms have been identified as potential causes of denials of and delays to radioactive material transports. WNTI offers software that presents correct labelling and marking and the information that should be presented based on the IMDG Code.[253] WNTI also produces an array of good practice guides. At the front end, these include guides on best practices such as: Uranium Concentrates: Industry Good Practices for ISO Containers in Multimodal Transports;[254] WNTI Best Practice for Checking Shipping Containers Prior to Loading Drums of UOC and Before Dispatch;'[255] and the Good Practice for Security of Drums of Uranium Ore Concentrate in 20' ISO Containers which provides guidance on methods for loading drums inside ISO containers for shipment by rail, road and sea.[256] As one transport representative said, 'transport [of uranium] is all about education and the use of best practice.'[257]

4.5 UPSATs and IPPAS

The IAEA's Uranium Production Site Appraisal Team (UPSAT) programme assists States in improving the operational and safety performance of uranium production facilities. Initiated in 1995, the first UPSAT mission was requested by Brazil and conducted at the already operating Caetité mine located in Bahia in 2010. The second was held in 2013 in Tanzania to review Tanzania's readiness to oversee the uranium production cycle, with an emphasis on the not-yet operational Mkuju River Project. Although not frequently requested, UPSATs provide valuable advice on health, safety, environmental and social licensing for proposed or ongoing development resource programmes and their implementation.

[252] Discussion with Australian official, 18 June 2013.

[253] See Interactive software for Labelling and Documentation, WNTI Website: http://www.wnti.co.uk/media-centre/interactive-software-for-labelling-and-documentation.aspx. Accessed 15 June 2015.

[254] Uranium Concentrates: Industry Good Practices for ISO Containers in Multimodal Transports – Revision 0, February 2008: http://www.wnti.co.uk/media/44377/GPG5_EN_MAR13_V1.pdf. Accessed 15 June 2015.

[255] http://www.wnti.co.uk/media/44377/GPG5_EN_MAR13_V1.pdf. Accessed 15 June 2015.

[256] Good Practice for Security of Drums of Uranium Ore Concentrate in 20' ISO Containers, August 2011: http://www.wnti.co.uk/media/31688/GPG3_EN_MAR13_V1.pdf. Accessed 15 June 2015.

[257] Discussion with transport industry representative, 15 June 2013.

These missions could be further strengthened by including experts on security and safeguards in the review team to ensure '3S' (safety, security and safeguards) coordination. Their inclusion would strengthen the peer review of a state's policies, procedures and practices across the uranium production cycle. This is particularly relevant with the introduction of PP21 potentially capturing more source materials in a supplier country, as well as the eventual entry into force of the 2005 CPPNM Amendment, which will require UOC to be protected in domestic use, storage and transport. New supplier states in particular should be offered a full peer review, given that the international treaty environment they are entering is increasingly complex. For regulators with limited human and financial resources, 3S integration encourages harmonisation across government agencies to provide a more holistic (versus stove-piped) approach to uranium governance.

IAEA *International Physical Protection Advisory Service (IPPAS)* missions, as requested by States, are intended to guide a State to establish and maintain effective nuclear security, including physical protection at facilities and locations. In principle IPPAS missions can cover the nuclear security of UOC, but only to a limited extent, since IPPAS missions are benchmarked to the CPPNM and INFCIRC/225. It is thus more helpful for peer review of the regulator or competent authority. In 2011, the United Kingdom became the first nuclear weapon state to invite an IPPAS mission.[258]

4.6 Recommendations

1. Adding security and safeguards to UPSATs

Suppliers are required to manoeuvre in a far more complicated regulatory landscape than ever before. UPSAT missions would be further strengthened by including experts on security and safeguards in the review team to ensure '3S' coordination. New supplier states in particular should be offered a full peer review of the state's policies, procedures and practices across the uranium production cycle.

2. A comprehensive approach to uranium security

The IAEA technical guidance on 'Nuclear Security in the Uranium Extraction Industry' aims to provide states and operators with advice for defining and implementing a prudent nuclear security regime for the protection of UOC

[258] *Governing Uranium in the United Kingdom*, pp. 29-30.

against unauthorised removal. The tecdoc suggests that measures based on risk assessments and a graded approach should begin when uranium is being or has been concentrated, purified or transported. National reviews that would take into account the tecdoc would enhance approaches to ensure a comprehensive system that addresses outsider threats (physical protection measures), insider threats (inventory controls) or both (transport security measures).

3. Nuclear security culture and engagement

Security culture underpins an effective nuclear security regime. It requires regular information and effective technical and performance evaluation. It is most effective when it is comprehensive, covering the state, competent authorities, operators and other stakeholders across the entire nuclear fuel cycle. This is particularly relevant, as the number of ratifications of the 2005 Amendment to the CPPNM moves towards the required two-thirds of States Parties for its entry into force. This requires more interaction between industry and governments to encourage a nuclear security dialogue. This could include greater consultation and coordination with industry on national threat assessments and any changes to threat levels, which is vital for operators to be able to design and implement appropriate security systems. It also encourages greater confidence and transparency in communicating to the public and other stakeholders that the industry and its regulators have systems in place to respond to a security incident at any stage of the nuclear supply chain.

5. Tracking Uranium: Inventory and Export Controls

In 1945 scientists involved in the development of the world's first nuclear weapon argued in the so-called 'Franck Report' that if there was unlimited trade and employment of nuclear power, the fate of every pound of uranium should be recorded.[259] While it is standard practice today for drums to be labelled with weight and purity, and assays to be done before shipment and again upon arrival at the conversion plant, there is no global 'mine to conversion' tracking system. Major producers employ in-company controls within their supply chains, and a number of states have national databases for nuclear materials, although not all UOC in a state may be captured in these databases. The evolving nature of IAEA safeguards is driving changes to the methods and scope of reporting within the uranium industry, requiring further integration to allow regulators and the IAEA to verify all UOC within a State, both declared and undeclared.

As noted in the section on safeguards, INFCIRC/153 paragraphs 34(a) and 34(b) require States to report not only exports and imports of UOC, but also the quantity, composition and NNWS destination of 'any material containing uranium or thorium … unless the material is exported for specifically non-nuclear purpose.' This includes material containing even trace quantities of uranium or thorium (such as phosphates, mineral sands, coal and rare earth elements) if such material is exported for eventual use in a nuclear reactor. If it is not destined for use in the nuclear supply chain (such as for ceramics), then reporting is exempt. It is thus incumbent on states that may export uranium-bearing ores or UOC to apply prudent controls and evaluate the risk that uranium will be extracted for nuclear purposes, and if so, to apply appropriate controls to such exports.

Accordingly, the objective in establishing inventory and export controls is to ensure a 'nationally appropriate' system of reporting to account for and track the movement of materials in-country and to facilitate information-sharing with countries where safeguarded uranium is exported abroad. Materials accountancy, coupled with a system of controls to evaluate the risk of exports in line with treaty obligations, UN sanctions and non-proliferation policies, further strengthens the safeguards regime while contributing to a state's nuclear security regime. Effective material

[259] "The 'Franck Report'. A Report to the Secretary of War", June 1945, http://www.fas.org/sgp/eprint/franck.html

accountancy will make it possible for regulators and the IAEA to verify industry's holdings and transactions independently while also enhancing effective security practices. These measures also protect government revenue (such as royalties and taxes) and build both public and international confidence in the safety and security of the nuclear industry.

5.1 Inventory Controls

Inventory controls provide accurate, timely, complete and reliable information on the location, quantities and characteristics of UOC and its custodial transfers. Effective inventory controls help detect and deter unauthorised removal while providing data useful for responding to and recovering missing UOC. The IAEA technical guidance on Nuclear Security in the Uranium Extraction Industry[260] recommends that national regulatory bodies require inventory controls based on a graded approach, applying engineering and administrative controls to track UOC at the last stages of processing (from solvent extraction, precipitation, drying, calcining, packaging), during storage and while in transit.

The biggest challenge to tracking materials is the sheer quantities involved. If a country is producing 20 million pounds (over 9,000tU) a year, and we take into account one per cent variability or loss, that one per cent can represent a lot of material (i.e. 20,000lbs or one metric ton short of a significant quantity). In Kazakhstan, with an annual throughput of over 20,000 tU, one significant quantity is approximately 0.05 per cent of the annual throughput. With such large volumes, not every rock can be tracked through the mill. There are additional technical challenges in accurately quantifying uranium content for all input and waste streams and calculating hold-ups in a processing facility. Inputs for a concentration plant, for example, can include phosphates and fertilisers, along with mineral water and water from the mine.

The concentration of uranium within ore also varies significantly, making it difficult to determine input streams. Radiometric scanning is used to determine whether the uranium concentration of ore exceeds a threshold activity to enter the process.[261] The radiometric scanners provide qualitative data on uranium content, making it impractical to determine inputs accurately until the uranium

[260] IAEA TECDOC – DRAFT, Nuclear Security in the Uranium Extraction Industry, Appendix IV: Graded Approach to Practical Implementation of Inventory Control (IC) Measures, Vienna 2014.

is fully dissolved into solution. The uranium inventory is thus estimated only for a portion of the process.[262] Additionally, the size and accessibility of processing equipment and the heterogeneity of process materials make it difficult to determine with precision the inventory of uranium at various stages in the process, while the chemicals used to extract, recover and concentrate uranium limit the accuracy of measurement systems further. To this end, the regulatory authorities and the industry take a graded approach to reporting requirements associated with the loss, theft or diversion of UOC.[263]

Ledgers, Barcodes and Inventory

Industry has a commercial interest in tracking their products and maintains inventories of materials. Drums are marked with unique identification numbers that are tied to the production lot number, allowing producers to trace the contents of a drum to a batch of product. This information is either painted on to the container using stencils or by applying pre-printed labels. Labels list information (usually applied by a felt marker) on purity and weight. Empty drums are weighed on approved scales to determine a tare (baseline) weight, although some producers may simply use the declared tare weight listed by the drum manufacturer, given they are made to uniform standards. The same scales weigh filled drums to determine gross UOC weight, with the difference between the gross and tare weights being attributed to the inventory of an individual drum.[264] Upwards of 30-50 drums, or one to two significant quantities of natural uranium, are then loaded on to shipping containers and shipped to the conversion or fuel fabrication plant, where they are again weighed on scales (which are usually calibrated every day) and moisture assays are taken. If there are differences between shipper and receiver, contractual arrangements usually provide for third-party reviewers. Differences are reported to the regulatory authorities, effectively managing the risk of diversion during transport.

Industry is able to detect the loss or theft of a single UOC drum within one to thirty days at mines, mills or during transport. Drum filling and inventory management processes are automated at many facilities. Despite the automation, drums are

[261] Ore that does not meet the levels defined by the facility is placed in a waste pile to be processed at a later date if market conditions are favourable. Ore that meets the threshold is processed further.

[262] Brent McGinnis,' An Overview of Process Monitoring Related to the Production of Uranium Ore Concentrate,' Innovative Solutions Unlimited, LLC, January 2013, p. 9.

[263] Ibid., p. 3.

[264] Brent McGinnis,' An Overview of Process Monitoring Related to the Production of Uranium Ore Concentrate,' Innovative Solutions Unlimited, LLC, January 2013, p. 14.

labelled and recorded in paper ledgers, although various electronic formats have largely replaced the traditional ledgers reducing the potential for transcription errors when transferring information between systems. However, the fact that automated systems do not extend to drum labelling or barcoding seems counterintuitive in the digital age, particularly at newly built multimillion-dollar facilities. Barcoding does raise additional security concerns related to cyber-security and the potential for proliferators to make 'dummy lots'. However, computer-based tracking and management systems for IDs are already widely employed by the industry, prompting companies to incorporate a range of controls to protect electronic data.

The output from approximately 50 global uranium mines is delivered to only a handful of converters (Canada, China, France, Russia, and United States). This concentration of facilities greatly simplifies the task of tracking uranium and the provision of physical security. It also means that conversion facilities face the greatest struggles regarding inventory controls as they can amass large volumes in their storage lots. While the inventory of a shipment is reconciled by the shipper and receiver at the gates of the conversion facility, drums can be stored at conversion plants for years. Converters do a physical count of drums on site regularly and know the areas where inventory of drummed ore is stored.

To increase its inventory efficiency, the Honeywell conversion facility in Metropolis, Illinois, recently began a pilot project to barcode the drums within its gates. As of April 2015, all drums entering Honeywell are now barcoded.[265] On receipt at the converter, each drum is uniquely identified with barcode labels and cross-referenced against the producer identification number. Since UOC is introduced into the process in accordance with strict blending criteria, the location and contents of each drum must be recorded for operational reasons. On the rare occasion that the drum identification has been lost or is unreadable drums may be identified by a variety of alternative means including physical location, drum type, identification of adjacent drums and comparison of weight and chemical composition. The application of modern high-performance labels coupled with first-in first-out feeding policies that limit the time drums are held in storage significantly reduces the likelihood drum identification will be lost.[266] The pilot project will be considered a success when it serves to improve the efficiency of the drummed uranium inventory process.

[265] Discussion representative from conversion industry, 28 May 2015.
[266] Discussion with conversion industry representative, 7 August 2015.

Uranium account balances detailing quantities, origins, and obligations are provided to all account holders monthly, and reconciled with the individual accounts holders. Individual owners of uranium perform audits to verify account balances, and convertors perform regular uranium counts of all physical uranium inventories. Converters also develop direct formal relationships with all global uranium producers and end-users independent of the contract relationships that exist between buyer and seller. This provides a second layer of oversight to prevent a producer from physically delivering or transferring ownership to a potential rogue entity.

5.2 National Databases

While full material accountancy and control does not apply to nuclear material until it becomes 34(c) material, Article 7 of INFCIRC/153 states that 'the State shall establish and maintain a system of accounting for and control of all nuclear material subject to safeguards under the Agreement…'. Accordingly, while exports or imports of pre-34(c) material do not require full accountancy and control reporting to the IAEA, there is a requirement for states to be able to account fully for UOC within a State.

The application and scope of material accountancy and control varies across the countries studied, particularly in the NWS and NNWS, and also where materials are captured under Policy Paper 18. Generally, the nuclear weapons states do not have material balance areas (MBAs) for mines and mills, although they do for conversion facilities. The MBA is the nuclear material accounting area for reports made to the IAEA and forms the basis of a state system for accounting and control (SSAC) for 34(c) material where the quantity of nuclear material in an area in or outside a facility can be determined for IAEA safeguards purposes. MBAs provide a single point for import and consolidation of inventories, a single database that records and tracks ownership, origin, obligations and transfers of title, as well as a concentration of expertise and the ability to identify any abnormal events or trends. Material crossing the boundary of an MBA must be reported as an inventory change, and all material within the boundary reported as physical inventory. Movements of material within an MBA do not need to be reported to the IAEA unless the material transforms, and category or batch structures change.[267]

[267] IAEA, Nuclear Material Accounting Handbook, IAEA Service Series, No. 15. Vienna, Austria, May 2008, p. 6.

In the United States, the Nuclear Regulatory Commission (NRC) does not require uranium producers to report UOC inventory to the Nuclear Material Management and Safeguards System (NMMSS) database unless they are storing foreign obligated UOC. Domestic UOC is only entered into NMMSS when it is shipped from the concentration plant to a conversion facility.[268] Mills in the United States are required to report annual production to the NRC for Additional Protocol declarations, but these amounts are not registered into NMMSS. In Russia, Rosatom developed an Automated Transportation Security System (ATSS), which consists of a network of control stations for real-time monitoring of the location of vehicles carrying nuclear materials and monitoring physical protection systems along the way. However, the information available suggests that natural uranium transport operations are not subject to ATSS monitoring.[269]

In Canada, the Canadian Nuclear Safety Commission (CNSC) manages the electronic national system known as the Nuclear Material Accounting System (NMAS). Nuclear material accounts are received from operators and inputted and reconciled in NMAS on a monthly basis and closed on an annual basis as part of the Physical Inventory Verification (PIV) exercises. Under NMAS, Group 1 material is material classified as subject to IAEA full scope safeguards (which in Canada starts with the introduction of UOC feed to Cameco's Blind River), and it requires detailed and regular nuclear material accounting and reporting to the CNSC.[270] Group 2 is source material excluding both ore residues and depleted uranium, and therefore is 'pre-34(c)' material. Although Group 2 is not subject to full material accountancy, the CNSC does require inventory change documents (ICD), which register increases and decreases in nuclear material. Licensees are required to report to the CNSC on the business day following the transaction.[271] Foreign obligated Group 2 material also has to be reported annually on 31 January, as well as upon the request of the CNSC. As such, all mines and mills in Canada have a MBA code.[272]

[268] 'Instructions for Completing Nuclear Material Transaction Reports (DOE Forms 741 and 740M)', United States Nuclear Regulatory Commission, NUREG/BR-0006, Rev. 7, January 1, 2009.

[269] *Governing Uranium in Russia*, p. 43.

[270] There is a distinction between Group 1A and Group 1B material. Group 1B is material that has been temporarily exempted, although it is expected to be re-classified as Group 1A (reportable) material when conditions for Group 1B are no longer met.

[271] Individual items are reported. If the number of items in inventory are very large (as is usually the case with UOC), the items can be grouped into a batch, and it is the number of items in the batch that is reported. The element and isotope weight of each item or batch on the List of Inventory Items is reported in unrounded numbers.

[272] Canadian Nuclear Safety Commission,'GD-336: Guidance for Accounting and Reporting of Nuclear Material,' updated March 2014.

For operators in Canada, the introduction of Policy Paper 18 and the implementation of integrated safeguards have led to an increase in the provision of information, a requirement to submit information directly to the IAEA and a change in the timing of submissions.[273] In the past, the CNSC would receive ICDs in hard copy format via courier, mail or fax in a variety of layouts, which were inputted into NMAS by two dedicated administrative clerks, who in turn put it into the format for IAEA reporting – an onerous and time-consuming process. In 2008, the CNSC introduced a dedicated email address to receive reporting digitally (with encryption). In modernising the system and moving towards an integrated electronic system, the CNSC adopted machine-readable electronic forms to permit facility operators to upload material reporting directly to NMAS easily and securely. The CNSC published new requirements and guidance documents which provide information on how new reporting requirements are to be met.[274] They became effective as of 1 January 2011. With standardised requirements in place, Canada becomes one of only a few states to provide the IAEA with near real-time accountancy data from approximately fifty different material balance areas, enabling the IAEA to be more effective in planning inspections and analysing declarations.[275]

Australia's permitting system sets material accountancy requirements, which include establishing an accounting system, material measurements, record-keeping preparation and submission of reports. All permit-holders for uranium mines are required to implement accountancy measures that have uncertainties of 0.1% for the mass of yellowcake in a drum and 0.2% for determining the total uranium concentration in the product.[276] Although this detection threshold is approximately equal to NSG reporting requirements for 34(a) and (b) imports or exports, which are 500kgU, the Australian measurements requirements are not linked to it. Australia reports its exports monthly to the IAEA. ASNO manages the Nuclear Material Balances and Tracking (NUMBAT) database system to fulfil reporting requirements under its IAEA safeguards agreement, track Australian obligated nuclear material overseas and maintain a register of permit-holders, as required

[273] Jennifer Sample, 'Establishing and Advancing Electronic Nuclear Material Accounting Capabilities,' Paper presented at the 2014 IAEA Safeguards Symposium, Vienna, Austria, October 2014.

[274] *Accounting and Reporting of Nuclear Material RD-336* and the *Guidance for Accounting and Reporting of Nuclear material GD-336*.

[275] Jennifer Sample, ibid.

[276] Brent McGinnis,' An Overview of Process Monitoring Related to the Production of Uranium Ore Concentrate,' Innovative Solutions Unlimited, LLC, January 2013, p. 9.

under the 1987 Safeguards Act. Initiated in February 1981, the NUMBAT program has evolved over the decades from operations on a HP250 Business Computer to Microsoft Access, and today it is undergoing a major digital upgrade and creating a completely new database to cover permit-holders, all nuclear material in-country, tracking of AONM and paragraph 34(a) reports (including those under the voluntary reporting scheme).[277]

Australian industry also refers to product stewardship in its corporate materiality assessments. Paladin mentions product stewardship 'throughout the lifecycle of product', while Rio Tinto refers to the importance of product stewardship in its materiality analysis.[278] The Minerals Council of Australia (MCA) also publishes the Uranium Forum Code of Practice and Stewardship, which defines principles of behaviour and standards of best practice to guide improvements for industry to operate 'with discipline in establishing and maintaining a strong record of performance'.[279] It calls for the implementation of effective and transparent engagement and independently verified reporting arrangements with stakeholders.

Reporting losses varies from country to country. For example, the NRC requires that 15lbs/U lost in a month or 150lbs/U in a year[280] be reported, while Canada requires that all losses be reported, and Australia expects the accountancy system to 'provide for the timely investigation of any accounting anomaly indicating a possible loss of UOC'.[281] India also requires industry to report losses within 24 hours.[282] Permit-holders in Australia are required to have controls in place that are capable of reporting the detection of any loss, theft or diversion within a two-hour period. In all cases it is incumbent upon industry to self-report, and none of the three large producer countries have ever received such a report. Anecdotal evidence suggests that industry loses small amounts on a regular basis.[283] The goal for national regulation should therefore define realistic amounts for reporting, and industry–government dialogue is needed to understand why industry does

[277] Australian Safeguards and Non-proliferation Office, Annual Report 2013-2014, Section 2.

[278] France Bourgouin, DIIS Report, p. 24.

[279] The Minerals Council of Australia – Uranium Forum Code of Practice and Stewardship: http://www.minerals.org.au/file_upload/files/resources/uranium/Code_of_Practice_and_Stewardship.pdf. Accessed 15 June 2015.

[280] NRC Regulations CFR Part 40—Domestic Licensing of Source Material.

[281] Discussion with Australian official, 16 June 2015.

[282] Nayan, *Governing Uranium in India*, p. 50.

[283] Discussions with officials and industry representatives from three major uranium-producing companies over the course of 2013 and 2014.

not report (e.g. too much paperwork for small amounts unaccounted for). This reporting would further help material accounting and information offered to the IAEA's ITDB to provide a realistic global understanding of the risk of theft and diversion.

Although the Model Additional Protocol does not require full material accountancy, its ratification is having a positive impact on accountancy and controls, given its requirements for States to report the location, operational status and annual production from uranium mines. During complementary access visits, the IAEA can take samples of UOC to reconcile a state's declaration with actual composition and purity on site. The Agency also employs other information-gathering sources such as satellite imagery that can be used to further verify declaration at mines and mills. In Kazakhstan, all information regarding Articles 2(a)(v) and (vi) that specify the location, operational status, and estimated and current annual production capacity of uranium mines and concentration plants are checked, confirmed, matched and consolidated by one office for all Kazatomprom companies. A unified system is used at various ventures holding all licenses and permits related to the production and processing of minerals and mineral materials, including the transport and storage of radioactive substances and waste. Every transfer of material is registered. These reports are then sent to the Kazakhstan Atomic Energy Committee (KAEC), which drafts Kazakhstan's AP reports and sends them to the IAEA. The annual declaration is not sent without Kazatomprom's internal sign-off. [284]

Kazakhstan's controls begin with empty drums. Astana enforces a quota system (the only country studied by the project that does so) in which companies are required to meet projected annual production figures within one per cent of the target total.[285] With quotas comes the risk of uranium produced 'off the books', that is, companies over-reporting during lean years and underreporting during better ones to meet their quota requirements. In 2009, Associated Press stated that it had acquired an IAEA intelligence report claiming that Iran was close to buying 1,350 tonnes of yellowcake from Kazakhstan for US$450 million.[286] The accusations were strongly denied by Kazakhstan, stating that an internal review had revealed no contract or contact between Kazatomprom and Iran.

[284] Discussion with Kazatomprom official, 20 October 2014.

[285] Discussion with KATCO official, 30 October 2014.

[286] 'Is Iran Running Out of Uranium?' *Time*, 27 April 2010: http://content.time.com/time/world/article/0,8599,1984657,00.html.

Kazakhstan stressed that its Law No. 300-III of 21 July 2007 'On Export Controls' does not permit exports to any NNWS without an end-user, and if Iran were to show up as a destination, controls would not allow shipments in violation of UN Security Council Resolution 1737.[287] Whether any such deal had existed or not, the accusations rattled Kazakhstan and led to the KAEC requesting assistance from the US Department of Energy and IAEA. The assistance addresses Kazakhstan's regulatory, technical and financial resources to conduct independent assessments and verify annual throughput at individual mines and concentration plants.[288] In 2012, Kazakhstan established the Regional Training Center for Accountancy, Control and Physical Protection of Nuclear Materials and Facilities. The centre provides training to Kazakhstani and other foreign officials on material accountancy and control and physical protection in line with IAEA recommendations.[289]

There is recognition among both newcomer and traditional suppliers that uranium is not like any other rock, and the regulatory authorities of several African states have requested assistance with the governance of uranium production and trade. The IAEA's Department of Nuclear Security has provided national training on its technical guidance document to Zambian officials in 2014, and again in June 2015 for African regulators and industry regionally. These regulators are generally constrained by a lack of financial and human resources, as well as by some countries lacking experience in nuclear legislation. Given the seriousness of diversion or misuse, or even the suspicion of such potential, the goal for all producers is to ensure controls are not only in place, but also implemented and enforceable.

5.3 Flag swaps

The uranium industry applies the practice of 'flag swaps', by which uranium originating from one supplier can be re-labelled under the nationality of another supplier to minimise transport costs, ensure the timeliness of product availability at contract-specified quantities, meet unexpected demand requirements and optimise

[287] 'Kazakhstan Strongly Denies Report of Potential Uranium Transfer to Iran,' *Aftenposten.no,* 31 December 2009: http://www.aftenposten.no/spesial/wikileaksdokumenter/31122009-KAZAKHSTAN-STRONGLY-DENIES-REPORT-OF-POTENTIAL-URANIUM-TRANSER-TO-IRAN-5107076.html.

[288] Brent McGinnis,' An Overview of Process Monitoring Related to the Production of Uranium Ore Concentrate,' Innovative Solutions Unlimited, LLC, January 2013, p. 26.

[289] The Nuclear Security Summit Progress Report 2012, An Arms Control Association and Partnership for Global Security Report July 2013, p. 12.

inventories. These book transfers are used when a physical transfer would be allowed, but the actual physical transfer can be avoided by 'swapping' materials at facilities. Although simple in principle, swaps of nuclear material can be complicated by the various physical and legal characteristics of the nuclear fuel, including the isotopic composition, location, mining and customs origins, safeguards obligations and ownership. There are several different types of swaps which need to be kept in mind when developing a system of material accountancy, including 1) ownership (or title) swap, 2) obligation (or flag) swap and 3) loan exchanges. All require national guidance, a system of reporting and procedures for prior approval.

Ownership Swaps

An ownership swap is a mutual change of ownership of two quantities of nuclear material, normally involving material of the same chemical form without a physical transfer. An example of ownership swaps would be where Utility A delivers its UOC to a North American converter and has an enrichment contract with an EU enricher, while Utility B has a contract for UOC with an EU converter with enrichment contracts in North America. Utilities therefore swap ownership of the material but not locations, allowing both to avoid transatlantic transport of the UOC to service their enrichment contracts. Sometimes material of different compositions are swapped, such as UF_6 for U_3O_8, resulting in a purchase of the conversion service of the material by the party receiving the UF_6. Ownership swaps are accomplished through book transfers between the accounts of the operators where the material is located.[290] They allow parties to obtain ownership of UOC of different national origins.

Table 6. Ownership Swap

	Utility A	*Utility B*
Before	Location A Origin X Obligation K	Location B Origin Y Obligation L
After	Location B Origin Y Obligation L	Location A Origin X Obligation K

Source: World Nuclear Association, 'Swaps in the International Nuclear Fuel Market', Report No. 2015/003, p. 7.

[290] World Nuclear Association, 'Swaps in the International Fuel Market,' Report No. 2015/003, April 2015, p. 7.

Obligation Swaps

Obligation or 'flag' swaps occur when the national obligation of uranium products is swapped without an exchange of ownership. Given that these transactions switch 'obligations', they are conditioned on bilateral treaty requirements and therefore require the permission of the national authority for tracking materials. In some cases, they are restricted in that they cannot result in a weakening of the non-proliferation regime. Internal (in-country) obligation swaps are frequent transactions done within the same country or jurisdiction. Australia, Canada and the United States allow internal swaps under their NCAs.[291] In the EU, obligation swaps within one material balance area do not need prior consent from the European Supply Agency, but consent is required if they are swapped between two MBAs. In the United States, obligation exchanges involving different enrichments require advance approval, otherwise it is understood that no approval is needed for domestic obligation exchanges concerning natural uranium or enriched uranium of the same enrichment. Exchanges are reported routinely to the NRC.[292] An example of an internal flag swap would be where a company in Canada has Namibian UOC in one facility and Australian obligated nuclear material in another and exchanges their flags without changing the safeguards requirements of the quantity and quality of material obligated within country.

Conversely, an international obligation swap switches safeguards obligations to equivalent quantities in different countries. As with internal swaps, the ownership and physical location of the materials remain the same. These exchanges are rarely used, however, as they can involve lengthy procedures in some countries to

Table 7. Obligation Swap

	Party 1	*Party 2*
Before	Location A Origin X Obligation K	Location B Origin Y Obligation L
After	Location A Origin X Obligation L	Location B Origin Y Obligation K

Source: World Nuclear Association, 'Swaps in the International Nuclear Fuel Market,' Report No. 2015/003, p. 7.

[291] Discussion with Australian official, 16 June 2015.

[292] World Nuclear Association, 'Swaps in the International Nuclear Fuel Market,' Report No. 2015/003 pp. 7-8.

obtain the consent of authorities in both countries. Australia, Canada, Euratom and the United States provide consent on a case-by-case basis. Euratom allows obligation swaps if the same quantity or quality of material is subject to the most restrictive obligations, while the US and Canada do not allow swaps where there is a proliferation concern. Australia's NCAs with Euratom and the United States provide permission for international obligation exchanges. Obligation swaps, whether internal or international, do not change the mining or customs origins of the materials.[293] It should also be noted that the origin may not be swapped for dual-obligated material in which the origin is the same.[294]

The WNA notes that, since few international flag swaps have been requested, authorities in supplier countries have not made the effort to streamline procedures.[295] However, the appetite for streamlining is not related to the infrequency of requests, but mainly to concerns that material accountancy, tracking and controls are uneven across states.

Loan Exchanges

A loan is defined as a transaction whereby the owner of the material transfers the ownership and/or the right of use and consumption of the material to another party, later receiving an equivalent amount of material with different characteristics to the material loaned. A loan of surplus inventories achieves essentially the same effect as a sale and future buy-back transaction between the same parties. Normally there is an economic benefit to the owner derived from the party which uses the material during the period of the loan. The difference between a loan exchange and an ownership swap is the timing of transfers between the parties. Ownership swaps are carried out almost simultaneously, while exchanges of loans may be separated by months or even years.[296]

There are also two types of origin that must be taken into account: geographical origin (country where the U_3O_8 is mined and milled) and customs origin (place where substantial transformation of material occurs). In their paper on swaps the World Nuclear Association notes that customs origins may be placed by countries where the material is substantially processed. It uses the example of Namibian UOC

[293] Ibid., p. 8.

[294] Discussion with Australian official, 16 June 2016.

[295] World Nuclear Association, 'Swaps in the International Nuclear Fuel Market,' Report No. 2015/003, April 2015, p. 8.

[296] Ibid., p. 9.

converted to UF_6 in France, which could be considered French-origin for customs purposes. Should the material be subsequently enriched in another country, such as the United Kingdom, it becomes UK-origin enriched uranium product (EUP) for the purposes of customs origin.[297]

The Namibia-France-Britain example used by WNA is perhaps an unfortunate illustration, given its allusion to a historical case. In the 1980s, Rössing's uranium was traded through a Swiss front company to evade the growing body of anti-apartheid legislation which prohibited importing resources from South African-occupied Namibia. France's Comurhex and British Nuclear Fuel Ltd (BNFL) replaced the Namibian origin flag with their own flags on the customs forms after they had converted the material into UF_6.[298] Similarly, Nulux, a Luxembourg subsidiary of Nukem, swapped uranium from Namibia to bypass Soviet and Finnish embargoes on material from apartheid South Africa.[299] Euratom claimed that, given the fungibility of uranium, its processing resulted in the loss of origin and nullified restrictions on use and transfer.[300] This 'UF_6 loophole' was designed to enable materials from South Africa and Namibia on to world markets.[301] An inquiry by the European Parliament into Euratom's practices[302] in the late 1980s noted concern over Euratom's flag-swapping practices and industry's numerous attempts to contravene the rules where 'the role of the [ESA] in such operations merits further investigation.'[303] In its report, issued on 24 June 1988, the European Parliament's

297 Ibid., p. 4.

298 At the time Rössing was owned by the Rio Tinto Group (RTZ), the Atomic Energy Organization of Iran (AEOI), the French-based total Compagnie Minière (TCF) and a South African entity, the Industrial Development Corporation (IDC), which controlled most of the voting shares. Before the mine was opened in 1976, RTZ had secured long-term contracts with German and Japanese utilities and with the UK Atomic Energy Authority. Ten years before, the UN Security Council 435 had ended South Africa's mandate to govern the territory and transferred that mandate to the UN Council for Namibia (UNCN) pending Namibia's independence and demanded the withdrawal of South African troops. The International Court of Justice (ICJ) ruled that the UN measures were binding, and in 1973 the UN General Assembly recognised the South West Africa People's Organisation (SWAPO) as the 'sole authentic representative' of the Namibian people. In 1974, the UNCN issued Decree No. 1, which prohibited the extraction and distribution of any natural resource from Namibian territory without the UNCN's permission. A number of western governments such as the United States and Britain did not accept the decree as binding. The UNCN embarked on a diplomatic campaign to boycott trade with Namibia and ending support to South Africa's occupation vis-à-vis taxes paid by the Rössing mine. See Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade*, Massachusetts Institute of Technology, 2012, p. 163.

299 Richard Bolt, 'Plutonium for All: Leaks in Global Safeguards,' *Bulletin of Atomic Scientists*, December 1988, p. 19.

300 Richard Bolt, ibid.

301 Ibid.

302 The review was sparked by a scandal not related to Namibian swaps. It was spurred when a new manager at a West German nuclear materials transport company, Transnuklear, discovered that employees had been given bribes in exchange for falsifying documents concerning shipments of radioactive waste. See Richard Bolt, ibid.

303 Bolt, ibid.

inquiry committee did not go so far as to claim the swaps were illegitimate, but it did emphasise that they should be limited to their original purpose.[304]

The concerns were not just with South African-origin material. In April 1988, the Australian Minister for Primary Industries and Energy referred to a case where a German company, Nukem, had swapped AONM for US nuclear material so that it could enrich the Australian material beyond 20 per cent without seeking prior consent from Canberra. In exchange, US-origin uranyl nitrate, a material unsuitable for uranium enrichment, was listed as Australian-origin.[305] The Australian Minister noted that the evidence available indicated the Euratom's approval of the transaction was consistent with the Australia-Euratom Safeguards Agreement.[306]

While the Namibia-France-UK example did not reduce the non-proliferation requirements of the material shipped, it serves as an example of how a supplier and a recipient can work together to defeat sanctions. It also demonstrates how swaps can be used to the economic benefit of one mine to the detriment of others that operate according to the law and the spirit of the law. At the time, Rössing's quantity of swapped material reportedly shot up from several hundred tonnes in 1982 to several thousand by 1985-1986. Rössing's profits also soared as sales contracts were negotiated in US dollars, but costs were incurred in South African Rand, a currency that was falling rapidly as opposition to apartheid gained momentum.[307] Accordingly, the case should not weaken the legitimacy of customs origins as a best (and necessary) practice as long as they are approved and do not switch or reduce obligations. Its historical underpinning does caution that the spirit of swaps can be misused to skirt around a country's commercial embargoes and underlines their potential for misuse.

Although a change in customs origin does not result in a change in mining origin, the approach to customs origins is different across states. The customs origin for U_3O_8 imported into the United States is the same as its geographical origin. For UF_6, the customs origin is the country where the uranium was converted, whereas Canada and Russia regard enrichment as the first stage at which a substantial

[304] Ibid.

[305] 'Canberra Dismisses Uranium Claims,' *The Age*, 21 April 1988.

[306] 'Australian Nuclear Safeguards,' Ministerial Statement, 20 April 1988: http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22chamber%2Fhansards%2F1988-04-20%2F0080%22.

[307] By 1985, Rössing had the highest profits to date, recorded at over 190m Rand after taxes, which was extraordinary given the depression in the global uranium market throughout the 1980s.

transformation takes place. The customs origin for U_3O_8 and UF_6 imported to Canada and Russia is the geographical origin of the country where the uranium was mined and milled. For enriched and fabricated material, the country of origin is the country where these processes take place. Euratom recognises substantial transformation and conversion, enrichment and fabrication, and consequently the customs flag is that of the country where the most recent transformation occurred.[308]

Multiple flagging also occurs, and fungible uranium is mixed with material generated and processed throughout the fuel cycle. As such the material can acquire a number of flags along its journey. This has led to a system of multiple flagging, where, for example, when Canadian obligated material becomes enriched in the US, it also acquires a US flag, and thus subsequent use will have to meet the NCA requirements for both Canada and the US. However, Canada's requirements regarding uranium exports do not apply to material imported into Canada for toll conversion and re-export. Brazilian ADU, for example, could be shipped to Canada for the purposes of conversion, with an equivalent amount of UF_6 returned to Brazil. Thus conversion in Canada does not of itself add Canadian obligations. US policy is that toll conversion, enrichment and fabrication bring material under the terms of the relevant bilateral nuclear co-operation agreement.[309]

5.4 Export Controls

All of the uranium supplier countries studied under the *Governing Uranium* project categorize uranium-bearing ores and their concentrates as a type of strategic resource and thus require government ownership or oversight, particularly for purposes of trade. For long-standing uranium producers and consumers, the guiding principle of classifying uranium as a mineral of a different sort is rooted in its explosive potential. Canada, for example, declared nuclear energy a matter of 'national interest' in its 1946 *Atomic Energy Control Act*, granting Ottawa exclusive jurisdiction. Uranium over 500ppm is considered a 'controlled nuclear substance' under the Nuclear Non-proliferation Import and Export Control Regulations.[310] Similarly, Australia in 1952 and India in 1962 both labelled uranium a 'prescribed

[308] World Nuclear Association, 'Swaps in the International Nuclear Fuel Market,' Report No. 2015/003, April 2015, p. 16.
[309] Ibid., p. 14.
[310] Nuclear Non-proliferation Import and Export Control Regulations, SOR/2000-210.

substance' subject to federal oversight in their respective atomic energy acts, while Brazil granted sole authority over uranium to the government in its 1988 Federal Constitution. South Africa also considers uranium a 'restricted material' in its 1999 Nuclear Energy Act, and more recently Namibia categorised uranium as a 'strategic mineral' in a Cabinet decision of 2007, as well as a potential energy production source.[311]

As a restricted material, export controls apply across states, although their application varies. Some countries, such as Brazil, produce uranium, export it for conversion, and then transport it back to the home country to be consumed. Brazil therefore does not export its uranium to utilities abroad. China, India, Russia and South Africa also do not export their domestically mined uranium abroad. Other countries such as Australia, Malawi, Namibia and Kazakhstan export all the uranium they produce. Canada consumes approximately 15 per cent of its own production, fuelling 20 CANDU reactors at three separate locations in Ontario and one in New Brunswick. The rest, nearly 85 per cent of Canada's total uranium production, is exported. At conversion facilities, there are also strict controls on the export of UOC. Except in exceptional circumstances, UOC may not be delivered from a conversion facility until converted to UO_2 or UF_6.

As ten of the countries studied are a party to the Nuclear Suppliers Group (NSG), the majority of export controls studied were based on NSG membership. Given UOC is on the NSG 'Trigger List', with the requirement for exports of 500 kg or more of natural uranium to be reported, there is a wide practice of providing government-to-government assurances unless a bilateral NCA is already in place with a particular country. Trigger list exports to all destinations, including those within the EU, require an export licence.

In the EU, EU regulation 428/2009 is in some ways tougher than NSG controls, extending them to smaller quantities of yellowcake than the NSG. It covers natural uranium 'in the form of metal, alloy, chemical compound or concentrate', although it does not provide for control where four grams or less are 'contained in a sensing component in instruments'.[312] EU and UN sanctions also ban the export

[311] Dougal Hammerslacht,'Uranium Mining 2000-2015: What Impact on the Namibian Economy?' 2012, CEPMLP Annual Review - CAR Volume 16 (2013), p. 9.

[312] COUNCIL REGULATION (EC) No 428/2009 of 5 May 2009, setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items, *Official Journal of the European Union*, L134/1, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:134:0001:0269:en:PDF

and import of natural uranium to and from Iran[313] and North Korea. In practice, export licenses for transfers to countries with nuclear weapons programmes, such as Israel and Pakistan, would also not be issued.

In the case of Australia, Canberra requires export permits for uranium-bearing ores and UOC over 500ppm, whether for nuclear or non-nuclear purposes. Risk assessments are then performed by ASNO and other ministries as necessary. In Australia, these risk assessments are based on four factors: quantity of nuclear material, extractability of nuclear material purpose of the export, and the nature of the safeguards that would apply should uranium be extracted. This process is similar to approaches to exports of dual-use goods under the Nuclear Suppliers Group. Australia then reports exports for nuclear purposes to the IAEA on a monthly basis, but it does not report exports for non-nuclear purposes because it has an export control system in place to satisfy itself that these exports are for 'specifically non-nuclear purpose.'[314]

The five countries studied that are not part of the NSG, namely India, Malawi, Namibia, Pakistan and Tanzania, have a spectrum of approaches. India and Pakistan do not export their uranium abroad while uranium production in Malawi and Namibia (and eventually Tanzania) is all for export. Namibia's Atomic Energy and Radiation Protection Act of 2005 requires licenses for uranium export. In Malawi, all consignments for exports are registered with the government before authorisation.[315] Both report their exports annually to the IAEA as per their safeguards agreements. According to the SIPRI report 'Africa and the Global Market in Natural Uranium,' both governments of Malawi and Namibia do not employ bilateral NCAs and therefore have no means of tracking their uranium once it is in the conversion facility.[316] The Tanzanian Atomic Energy Act of 2003 requires licenses for export.[317] Tanzania is currently partnering with the European Commission to review and enhance its legal and regulatory framework related to uranium mining.

313 Until sanctions are lifted as per the implementation of the Joint Comprehensive Plan of Action finalised on 14 July 2015.

314 Everton et al., 2011.

315 Presentation by Malawi, 'Regional Seminar on Uranium Mining, Milling, and Transport,' Brussels, 13-17 October 2014.

316 Ian Anthony and Lina Grip, 'Africa and the Global Market in Natural Uranium: From Proliferation Risk to Non-proliferation Opportunity,' p. 11.

317 The Atomic Energy Act, 2002, Part III.

5.5 Recommendations

1. Updating and modernising nuclear databases

Even though UOC is considered 'pre-34(c)' material, there are annual safeguards reporting requirements for UOC exports and imports. Accordingly, it is incumbent on states to have a system in place to account for all UOC within a state. The evolving IAEA safeguards system has led to an increase in the provision of information, the timing of submissions and the requirement to submit reporting directly to the IAEA. Establishing integrated digital inventory control systems will provide the IAEA with near real-time accountancy data, thus enabling it to be more effective in planning inspections and analysing declarations. Accompanied by standardised nuclear material accounting forms, record-keeping and guidance documents by national regulators, such systems will provide industry with clear information on how new reporting requirements are to be met.

2. Adopting digital tracking methods

Given that the majority of global UOC travels through a handful of commercial converters (in Canada, China, France, Russia and the United States), conversion facilities can amass large volumes in their storage lots for years. The use of digital tracking systems would alleviate the backlog and inventory challenges at conversion plants to provide almost real-time tracking. Similarly, barcoding could provide greater control and inventory efficiencies at mines/mills. While barcoding systems that are currently in place at some facilities are used internally, if coordinated between producer and converter, a more efficient and robust global 'mine to conversion' tracking system could be employed.

6. Conclusion

The uranium industry is highly complex and is continually being reshaped in response to increased competition, market internationalisation, nuclear accidents and geopolitical concerns. It is multinational, with public and private cross-ownership in which a number of interests – commercial, economic, strategic and non-proliferation – can overlap or collide. Adding to the complexity has been an evolving system of international nuclear treaties and obligations, accompanied by expanding geographies of consumption and supply. Today's buyers and sellers of uranium are functioning in a far more complicated regulatory landscape, with a larger number of actors and stakeholders than ever before.

The *Governing Uranium* project has mapped this complexity across fifteen producing and/or consuming states. It highlights that the nuclear industry is heavily regulated in the recognition that uranium is not like any other rock. Yet, as we mark seventy years of the nuclear age, the ability to piece together how uranium is tracked around the world is hampered by a four-tiered safeguards structure which has historically placed limited international controls on the front end of the nuclear fuel cycle.

An increasingly globalised civilian nuclear market requires greater harmonisation of regulations and best practices across all states – including the nuclear weapons states. Correspondingly, a better harmonisation of the '3S' (safety, security and safeguards) within and across states (and the IAEA) will further ensure the trade of UOC will function efficiently, cost-effectively and safely while providing a secure supply of nuclear energy. The goal is to develop robust, clearly-defined and streamlined systems of governance that are nationally-appropriate and internationally-mindful. After all, the nuclear fuel cycle is essentially global, and it all begins with uranium.

Annex I. Full List of Policy Recommendations

1. Benchmarking non-proliferation performance

Companies along the nuclear supply chain can strengthen the global nuclear regulatory regime through engagement, material stewardship and traceability. Private actors share a responsibility in being able to know where their uranium is sourced, how it is mined and the social and environmental impact of mining and transport operations, as well as being able to provide assurances that uranium has not been lost or accidentally diverted along the supply chain. For non-proliferation to be a fully effective tenet of corporate sustainability, it will need its own set of committed companies, standards-based performance indicators, and knowledgeable investors and consumers.

2. Controls on Brokering and Transit/Transhipments

Development and implementation of appropriate national laws or measures supplement a country's export controls by closing loopholes to catch additional nuclear trading activities, regardless of whether or not illicit brokering is involved.

3. Make clarifications to Paragraph 34(c) public

The revised definition of paragraph 34(c) creates new obligations for state regulatory authorities and facility operators. However, States, the industry and stakeholders cannot access the new definition without going to the IAEA first, which makes the process unduly bureaucratic and mysterious. PP21 does not need to be made public in its entirety, but any clarifications to paragraph 34(c), which is when full safeguards obligations under the NPT kick in, should be made widely available to the public, the industry, states and stakeholders.

4. Employ bilateral nuclear cooperation agreements

Employing bilateral nuclear cooperation agreements provides additional treaty assurances of peaceful uses. These state-to-state agreements frame the conditions for nuclear trade and allow for bilateral reporting mechanisms, information sharing, and prior consent for transferring, enriching or reprocessing the material.

5. Adding security and safeguards to UPSATs

Suppliers are being required to manoeuvre in a far more complicated regulatory landscape than ever before. UPSAT missions would be further strengthened by including experts on security and safeguards in the review team to ensure '3S' coordination. New supplier states in particular should be offered a full peer review of the state's policies, procedures and practices across the uranium production cycle.

6. A comprehensive approach to uranium security

The IAEA technical guidance on 'Nuclear Security in the Uranium Extraction Industry' aims to provide states and operators with advice for defining and implementing a prudent nuclear security regime for the protection of UOC against unauthorized removal. The tecdoc suggests that measures based on risk assessments and a graded approach should begin when uranium is being or has been concentrated, purified and transported. National reviews that would take the tecdoc into account would enhance approaches to ensure a comprehensive system that addresses outsider threats (physical protection measures), insider threats (inventory controls) or both (transport security measures).

7. Nuclear security culture and engagement

Security culture underpins an effective nuclear security regime. It requires regular information and effective technical and performance evaluation. It is most effective when it is comprehensive, covering the state level, competent authorities, operators and other stakeholders across the entire nuclear fuel cycle. This is particularly relevant as the number of ratifications of the 2005 Amendment to the CPPNM moves towards the required two-thirds of States Parties for its entry into force. This requires more interaction between the industry and governments to encourage a nuclear security dialogue. This could include greater consultation and coordination with the industry on national threat assessments and any changes to threat levels, which is vital for operators to design and implement appropriate security systems. It also encourages greater confidence and transparency in communicating to the public and other stakeholders the fact that both the industry and regulators have systems in place to respond to a security incident at any stage of the nuclear supply chain.

8. Updating and modernizing nuclear databases

Even though UOC is considered 'pre-34(c)' material, there are annual safeguards reporting requirements for UOC exports and imports. Accordingly, it is incumbent on states to have a system to account for all UOC within a state. The evolving IAEA safeguards system has led to an increase in the provision of information, the timing of submissions and the requirement to submit reporting directly to the IAEA. Establishing integrated digital inventory control systems will provide the IAEA with near real-time accountancy data, enabling the IAEA to be more effective in planning inspections and analysing declarations. Accompanied by standardized nuclear material accounting forms, record-keeping and guidance documents by national regulators, such systems will provide industry with clear information on how new reporting requirements are to be met.

9. Adopting digital tracking methods

Given that the majority of global UOC travels through a handful of commercial converters (in Canada, China, France, Russia and the United States), conversion facilities can amass large volumes in their storage lots for years. The use of digital tracking systems would alleviate the backlog and inventory challenges at conversion plants to provide almost real-time tracking. Similarly, barcoding could provide greater control and inventory efficiencies at mines/mills. While barcoding systems that are currently in place at some facilities are used internally, if coordinated between producer and converter, a more efficient and robust global 'mine to conversion' tracking system could be employed.

Annex II. Conversion Facilities Globally

It is generally reckoned that there are five countries operating commercial conversion facilities: Canada, China, France, Russia and the United States, that is, those that import and process uranium ore concentrates for global consumption. Although the United Kingdom closed the Springfields conversion facility owned by Westinghouse in August 2014, information on it is provided below in the 'commercial conversion' list.

As of 1 July 2015, there are eight operational commercial conversion facilities: two in China, two in Russia, two in France, one in the US and two (if we include refining) in Canada. This will be reduced to seven when Russia closes down the Chepetsk Mechanical Plant. There is also uncertainty about the operation of a third conversion facility in China.

Seven other countries operate conversion facilities for domestic use only and do not export their UO_2 or UF_6 abroad. These are located in Argentina, Brazil, India, Israel, North Korea, Pakistan and Romania.

Commercial Conversion

Canada [318]

Although technically a single process, the refining and conversion of natural uranium in Canada takes place at two separate facilities: refining in Blind River, and conversion in Port Hope, both located in the province of Ontario and both owned by Cameco Corporation.

Cameco Blind River was built in 1983 and receives UOC from mines and mills in Canada and around the world, which it refines into uranium trioxide (UO_3). Most of this is sent directly to Cameco Port Hope, although some is exported. The capacity of Blind River is approximately 18,000tU per year. The conversion plant at Port Hope has a longer history, going back to 1935 as a radium extraction facility. Today, it converts UO_3 into either UF_6, which is exported for subsequent enrichment, or UO_2, which is primarily used for the domestic production of

[318] Governing Uranium website: http://uranium.csis.org/pit_to_port/.

CANDU fuel. The throughput of the UF_6 plant is approximately 12, 500tU per year, while the UO_2 plant processes around 2,000tU per year.

China [319]

There is very little information publicly available on China's uranium conversion facilities, and there are differing reports on their operational capacity. China is commonly reported as having a UOC conversion capacity of 3,000tU per year, placing it far below the capacity of other international converters. The World Nuclear Association reports that a conversion plant at Lanzhou with a capacity of about 1,000 tU per year started operation in 1980 but may now be closed, and that another conversion plant at Diwopu in Gansu province has a capacity of about 500tU per year.

Due to the relatively small capacity of these plants compared to other international conversion centres, these facilities are most likely primarily dedicated to domestic supply needs. Despite the currently low capacity of China's conversion facilities, it is still serving as a commercial converter for foreign entities in certain cases. For instance, Uzbekistan, which mines 2,300 to 2,600 tonnes of uranium per year, is currently using Chinese facilities to convert its uranium. After undergoing further processing at the hydrometallurgical plant in Navoi, a portion of the uranium concentrate is shipped by rail to Alashankou in China's northwestern province of Xinjiang for delivery to Chinese conversion facilities.

Meanwhile, however, China's plans for further conversion capacity at the new China Nuclear Fuel Element Co. (CNFEC) plant at Daying Industrial Park in Heshan City, Guangdon Province, was cancelled in July 2013 in response to protests from the public.

France [320]

In 1958, France built a new conversion plant at Malvesi (inaugurated in 1969), releasing the facility at Le Bouchet, which had been operating since 1948, for special or complementary production. After Le Bouchet was closed in 1971, the COMURHEX plant at Malvesi became the only operational conversion plant in France. Physically, Malvesi serves as a 'warehouse' for most imported natural

[319] Ibid.
[320] Ibid.

uranium before the yellowcake is converted for either domestic use or re-exported for use abroad. By the end of 2010, stocks amounted to approximately 15,913 tonnes. AREVA's conversion facility at Comerhux Pierrelatte is scheduled to begin operation in 2015.

Russia [321]

Natural uranium is used by the TVEL Fuel Company, a subsidiary of Rosatom, to make nuclear fuel for Russia's own nuclear power plants (NPPs) and nuclear power plants in foreign countries, as well as to fulfil Techsnabexport contracts for uranium enrichment services and deliveries of enriched uranium product. As part of that process, natural uranium undergoes a conversion to uranium hexafluoride (UF_6) and is then delivered to uranium enrichment plants.

Until recently, Russia had three uranium conversion facilities in operation: the Siberian Chemical Combine (SKhK, Tomsk Region, Siberian Federal District), the Angarsk Electrolysis Chemical Combine (AEKhK, Irkutsk Region, Siberian Federal District), and the Chepetsk Mechanical Plant (ChMZ, Republic of Udmurtia, Volga Federal District). The former two facilities produced uranium hexafluoride (UF_6). The facility at ChMZ produced uranium tetrafluoride (UF_4), which was then supplied to AEKhK, where it was converted into hexafluoride. The combined annual output capacity of the three facilities was 25,000 tonnes of uranium (tonnes U as UF_6). According to various estimates, however, only 35-55 percent of that capacity was actually in use. The equivalent figure for large uranium conversion facilities in other countries is in the range of 70-85 percent.

As part of its optimization and cost-cutting program, the Rosatom state nuclear energy corporation has decided to concentrate all its UF_6 production at a single facility. The new conversion facility will be set up at SKhK to replace the existing one, which was built about fifty years ago for the Soviet nuclear weapons program. SKhK was chosen to host the new facility, among other reasons due to its easier logistics. The site offers advantages over ChMZ and AEKhK in terms of the convenience of transportation of raw materials (i.e. natural and reprocessed uranium) and the UF_6. The conversion facility at AEKhK was shut down on April 1, 2014. ChMZ will follow after the launch of the first stage of the new conversion facility at SKhK. An estimated 12 billion roubles (more than $350 million USD) will be spent on building the new Rosatom conversion plant.

[321] Ibid.

The new conversion facility will use natural as well as reprocessed uranium (RepU). Its projected output is 18,000tU per year for natural uranium, and 2,000tU per year for RepU. The launch of the new facility at SKhK is expected to slash Russian costs by 50 percent from $10 USD/kgU in 2014 to $5 USD/kgU. The facility will employ four hundred people, and the investment is expected to be recouped in eight years' time.

The original plan was to start building the new facility at SKhK in late 2013 and launch it in 2016. All these deadlines have now been pushed two years back because of the unfavourable market situation following the Fukushima nuclear accident. SKhK expects to obtain all the necessary licenses for the construction of the new conversion facility in 2015.

United Kingdom

Springfields, located near Preston, Lancashire in the UK was the first plant in the world to make nuclear fuel for commercial power stations. Opened in 1946, the conversion facility was closed in August 2014. In its first forty years of operation some 80,000 tU equivalent of uranium ore concentrate' had been 'converted to nuclear fuel or nuclear intermediaries at Springfields'.[322] In January 1990, the UK government noted in Parliament that total 'uranium consumption' for civil electricity production in the UK up to and including 1989 had been 38,800 tonnes.[323]

In April 2005 responsibility for the assets and liabilities of Springfields was transferred from British Nuclear Fuels Ltd (BNFL) to Britain's Nuclear Decommissioning Authority (NDA), a government agency established to take responsibility for the majority of the United Kingdom's civil nuclear assets and liabilities. At the same time, Springfields Fuels Limited was established to operate the site, which itself was managed and operated by Westinghouse Electric UK Ltd on the NDA's behalf. An agreement between the NDA and Westinghouse was reached on 1 April 2010 under which Westinghouse was given a long-term lease of the Springfields site and manages the 6,000t/yr licensed conversion plant.[324]

Over its lifetime, Springfields has processed imported uranium from just about all uranium-producing states. In 2008, it no longer operated the 'wet' solvent extraction

[322] Berkermeier et al., *Governing Uranium in the United Kingdom*, DIIS Report 2014:02, 2014, p. 19.
[323] Ibid., p. 10.
[324] Ibid., p. 22.

part of the front end of the fuel cycle for a combination of environmental and financial reasons and therefore did not receive uranium in the form of yellowcake, but as UO_3.[325]

According to the World Nuclear Association, Urenco is planning to build a 7000 t/yr deconversion plant, or Tails Management Facility, at Capenhurst, with commissioning expected in 2017p, after cost overruns and delays. It will treat tails from all three European Urenco sites: Capenhurst, Almelo in the Netherlands and Gronau in Germany. Depleted uranium will then be stored in more chemically stable form as U_3O_8.[326]

United States [327]

One conversion plant is operating in the United States, the Honeywell Metropolis Works Plant (MTW) in Metropolis, Illinois. The facility began operating in 1958, was mothballed in 1964, and rehabilitated and re-opened in 1968 as a private converter. ConverDyn was created in 1992 as a partnership between Honeywell and General Atomics and is the exclusive agent for conversion sales from Metropolis, including coordinating and managing conversion-related services to nuclear utilities in the USA, Europe and Asia. These services include uranium deliveries, sampling, material storage and product delivery. The MTW is capable of converting over 36 million pounds (16,000 tonnes) of U_3O_8 into UF_6 annually.

The MTW shut down production in May 2012 to address the upgrades required by the U.S. Nuclear Regulatory Commission (NRC) focused on preparedness for extreme natural disasters such as earthquakes and tornados. In November 2012, Honeywell began comprehensive upgrades at a cost of more than $40 million to reinforce the plant. Operations were restarted in July 2013 after NRC approval.

Domestic Conversion

Argentina

The conversion plant in Cordoba produces UO_2 via nitrate (NO_3/UO_3) from Argentinean yellowcake or impure (usually imported) U_30_8 with a design capacity

325 Ibid., p. 23.

326 World Nuclear Association, 'Nuclear Power in the United Kingdom': http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom/%23.UiH2qxY2-lI. Accessed 25 June 2015.

327 *Governing Uranium* website: http://uranium.csis.org/pit_to_port/.

of 200t/yr. The process implemented at Cordoba covers all the steps to filtering and purifying uranyl nitrate liquors and the corresponding steps to adjust the concentration in order to precipitate pure ammonium uranyl carbonate and its subsequent reduction to UO_2. After the reduction through the fluidized bed at high temperature, the pure UO_2 is stabilized and collected in 200 L drums. The final product in this step is usually called 'loads.' Once the results of the samples are available, the drums are conditioned for shipment and transferred to the storage area. The material in the storage area is called 'batches or lotes'. The 'loads/cargas' are considered material in process, while the 'batches/lotes' are the final products.[328] In this facility, natural or low enriched uranium scrap recovery campaigns are scheduled once or twice a year linked to the country's operational plans for the fuel fabrication plant. The feed material during these scrappage campaign is already under safeguards.

There is another plant located in Pilcaniyeu, Bariloche, which had a 60t/yr capacity to produce UF_6 starting from pure UO_2 and was already under ABACC/IAEA safeguards. This plant is in shutdown mode.

Brazil

In Brazil, the navy runs pilot and testing facilities for its nuclear propulsion programme at the Aramar Experimental Center, located in Iperó, Region of Sorocaba, in the state of São Paulo. Aramar's infrastructure includes a partially constructed uranium conversion plant which will produce UF_6 (via nitrate) for use in the Brazilian enrichment programme. The process route is UOC→ NO_3→ ADU→ UO_3 → UF_4 → UF_6. According to ABACC, the conversion plant at Aramar has been redesigned and is being constructed to allow for verification of material covered by PP18.[329] It has a design capacity of 40t/yr.

The plant process is the traditional wet route, with uranyl nitrate being the first step of pure material. It has a design capacity of 40t/year. The material will be used in the Brazilian enrichment programme.

India

The processing plant at Jaduguda in Singhbhum District, Jharkhand, processes ore from the Jaduguda, Bhatin and Narwapahar uranium mines. Extraction is by

328 ABACC paper, p. 5: http://www.abacc.org.br/artigos_antigos/Alternative%20Techniques.pdf

329 Discussion with ABACC officials, 25 March 2013.

hydro-metallurgical process. Ore undergoes two stages of wet grinding after three stages of crushing, producing magnesium di-uranate (MgU_2O_7). It is thickened, washed, filtered and dried in the spray dryer, and finally packed in drums and then sent to the Nuclear Fuel Complex at Hyderabad for fabrication into UO_2 pellets.

The Turamdih Processing Plant, located in Seraikella-Kharsawan District, Jharkhand, processes ore produced from the Banduhurang and Turamdih mines. It is currently being modernized and expanded to treat more ore. It uses the Jaduguda process and sends MgU_2O_7 to the Nuclear Fuel Complex in Hyderabad.

The Hyderabad NFC also processes imported UF_6 and converts it to uranium oxide for use in BWRs.

Iran

The Uranium Conversion Facility (UCF) at Esfahan contains process lines to convert yellowcake into uranium oxide and UF6. It began operations in June 2006. According to information provided to the IAEA, Iran carried out most of its experiments in uranium conversion between 1981 and 1993 at the Tehran Nuclear Research Center (TNRC) and other facilities at Esfahan.[330] In 1991, Iran contracted to purchase a turnkey, industrial scale conversion facility from China. This contract was cancelled, but Iran retained the design information and built the plant on its own. Construction of the UCF began in the late 1990s.[331]

Iran declared that it began construction of the UCF without building and testing a pilot scale plant. After extensive analysis, the IAEA accepted this declaration. Following the 2004 suspension agreement between Iran and the European Union, Iran stopped conversion activities at the plant in November 2004. In August 2005, Iran announced that it planned to resume conversion activities.[332]

The UCF consists of several conversion lines, mainly that for the conversion of yellowcake to UF_6. The annual production capacity of the UCF is 200 tonnes of uranium in the form of UF_6. The UF_6 is made for the uranium enrichment facilities at Natanz and Fordow. The UCF is also able to convert yellowcake, LEU and depleted uranium into uranium oxide and depleted uranium metal.[333]

[330] ISIS Nuclear Iran website: http://www.isisnucleariran.org/sites/detail/esfahan/.

[331] Ibid.

[332] Ibid.

[333] Ibid.

Israel

Israel is widely understood to possess a sizeable nuclear arsenal, but maintains a policy of nuclear opacity. It reportedly has a uranium conversion facility at Dimona that produces UO_2 which can subsequently be manufactured into fuel for the IRR-2 reactor.

North Korea

Not much is publicly available on North Korea's conversion capabilities, although it does seem that there are conversion activities located at the Yongbyon Nuclear site, which at least years ago, was known to convert yellowcake into UO_2. The uranium dioxide was then subsequently converted into metal at other facilities in the complex and made into fuel for the gas-graphite reactors, principally the 5 megawatt-electric (MWe) reactor.

Pakistan

The Chemical Plant Complex (CPC), at the Dera Ghazi Khan Nuclear Site processes yellowcake received from the mines in Baghalchur. With the development and greater use of in-situ leaching there is no need for milling, and the material from the mine is almost in the form of yellowcake, though it requires chemical processing and purification to remove other metals, etc.[334]

The chemical purification and finishing of product as UO_2 or UF_4/UF_6 is done at CPC. Reduction of uranium compound to uranium metal is carried out at UML, Atomic Energy and Nuclear Research Institute (PINSTECH), near Islamabad. All mining for uranium, its subsequent extraction and processing into UOC, chemical purification and refining into UO_2 – or any other chemically pure uranium compound – and fabrication falls within the purview of the Pakistan Atomic Energy Commission (PAEC) and is carried out solely by PAEC.[335]

Romania

Uranium ore is processed at Feldioara, owned by the National Uranium Company (CNU). It has two modules. One ('R' type) is for uranium milling and concentration, with an annual capacity of 300t/yr U_3O_8. The other ('E' type) is for refining and conversion to nuclear grade UO_2. Feldioara has been qualified by AECL as a CANDU UO_2 fuel provider. Both are operating at a reduced capacity of 100t/yr.

[334] Sultan et al., Governing Uranium in Pakistan, DIIS Report 2015:08, p. 37.

[335] Ibid.

The Feldioara plant was built in 1976 for the extraction of uranium from the ore (using the depression alkaline leaching technique). Uranium transfer from the Bihor and Banat mines to the processing plant at Feldioara started in 1977. The first samples of yellowcake (ammonium diuranate) were produced. Between 1983 and 1985 the Crucea–Botuşana mines were commissioned, as well as uranium ore delivery to Feldioara. Currently, the uranium needed for the normal life-cycle of the two CANDU reactors presently in operation at the Cernavodă NPP is ensured by the U_3O_8 and sodium diuranate (NaDU) stocks produced and stored at the Feldioara processing plant.[336]

In December 2008, the last uranium ore was dispatched from Bihor to the Feldioara plant, and today there is only one region with operational mines (the Crucea and Botusana mines), located in the Suceava region (North). According to figures from 2012, these mines can supply enough uranium for the Cernavoda reactors for another eight to ten years.[337]

Kazakhstan

Kazatomprom in Kazakhstan is considering building what would be its first uranium refinery plant, following a 2012 agreement with Cameco. The project is still in the design stages.

[336] https://ec.europa.eu/energy/sites/ener/files/documents/tech_report_romania_2012_en.pdf, p. 21.

[337] European Commission, Directorate – General for Energy, 'Uranium mining, Processing, Fuel Fabrication and National Monitoring Networks (Romania)', 20-24 August 2012, p. 22.