Emerging proliferation risks imposed by a nuclear growth scenario

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ABSTRACT: Climate change, future energy demand and security of supply are the major reasons for several countries around the world to introduce nuclear energy in their domestic energy production portfolio. This nuclear growth is strongly correlated to an emerging nuclear proliferation risk. The latter is driven by the need of more enrichment facilities in order to supply enough material for the nuclear power reactor fleet. In order to tackle the nuclear proliferation risk intrinsic and extrinsic features are needed, such as more proliferation resistant technologies in the nuclear fuel cycle and enhanced safeguards.

Keywords: Nuclear proliferation, nuclear growth scenarios, emerging risk, nuclear fuel cycle

1. INTRODUCTION

1.1 Background

For several years new investments in nuclear energy have been proposed by international institutions (IEA, IAEA), arguing with future energy demand, and security of supply and climate change mitigation strategies. Outside of Europe, the accidents at the Fukushima Daiichi nuclear power plants only had limited influence on the plans of introducing nuclear power and/or enlarging the installed nuclear capacity. The emerging interest in nuclear power and the expected growth of installed capacity in certain areas of the world, with many newcomer states making preparations for their first nuclear power plant, revealed the need for an analyses of the global nuclear fuel cycle and potential emerging proliferations risks (Ahearne, 2011; Arnold and Gufler, 2012; IAEA, 2012; IEA, 2013).

1.2 Objective and Approach

The primary objective of this work is to identify the necessary capacities of the future nuclear fuel cycle in order to supply the expected nuclear power reactor fleet. This provides the basis to analyze the potential proliferation risk induced by a growing amount of nuclear fuel cycle facilities. Besides the technical analysis, a socio- political approach is needed to cope with the identified question. In order to understand the dynamics of the development and potential implications a comprehensive analysis is needed, combinig both technical and socio-political aspects.

2. Nuclear power scenarios

2.1 Status of nuclear power in 2014

The current nuclear power reactor fleet consists of 435 reactors in 31 countries with nominal 372 GWe net installed capacity (IAEA, 2014a). In the beginning of 2013 61 reactors in 13 countries and by June 2014 72 reactors in 14 countries were under construction (Gufler, 2013; IAEA, 2014a). Additionally 202 units were in a planning phase in 18 countries in 2013 (Arnold and Gufler, 2014). Projections and scenarios indicate a constant growth of nuclear installations on a global level – with a focus on developing economies in Asia including previously non-nuclear countries.

The operating nuclear power reactor fleet is based on uranium as fuel and also the new reactors under construction follow the same pathway. The current reactor fleet is supplied with uranium from primary and secondary sources. Primary sources are derived from direct mining production, secondary sources comprehend stocks, as well as uranium originating from the reprocessing of spent fuel and downblended weapons-grade uranium. (Arnold et al., 2011; Gabriel et al., 2013; Zittel et al., 2013).

2.2 Status of nuclear fuel cycle facilities in 2014

The nuclear fuel cycle consists of five steps on the front end[1] (mining, milling, conversion, enrichment and fuel fabrication) and on four steps on the back end (spent fuel storage, reprocessing, fabrication of mixed uranium-plutonium fuel and spent fuel disposal). For the present study the scope was reduced to the front end, because the handling of material vulnerable to proliferation

[1] The steps necessary before uranium can be loaded into a nuclear reactor are summarized by the term “front end”. The handling of the nuclear material, after it has been used in the reactor, is called the nuclear back end.

is much easier at this stage. In the front end the main focus is on the enrichment, as this step is the most relevant stage in the front end when it comes to nuclear proliferation. (IAEA, 2014b)

The enrichment facilities are located in 12 countries (Argentina, Brazil, China, France, Germany, Iran, Japan, Netherlands, Pakistan, Russian Federation, United Kingdom, and United States of America). 31 countries are having nuclear power within their energy mix, 23 countries have nuclear fuel cycle facilities – 4 of them have no operating nuclear power plants. Around 60% of the countries using nuclear power are capable of at least one step of the nuclear fuel cycle mentioned in the paper. (IAEA, 2014b)

On a global level in 2014 there are 22 conversion facilities (21 commercial) in operation, 1 planned, 3 under construction, 19 enrichment facilities (14 commercial) in operation, 2 planned, 2 under construction, 54 uranium fuel fabrication facilities (42 commercial) in operation, 1 planned and 19 spent fuel reprocessing and recycling facilities (9 commercial) in operation, 2 planned, 2 under construction. (IAEA, 2014b)

2.3 Nuclear power projections and scenarios

There are several projections, scenarios and forecasts published by different institutions – private and institutional. Nuclear power is included by most of the institutions publishing energy scenarios. Two growth scenarios were selected – one assuming a strong increase of nuclear generation capacity, and the second one assuming a even stronger increase, since unchanged capacity scenarios do not affect the current proliferation risk. Nevertheless there are several projections and scenarios which indicate a much weaker growth than the selected projections on a global level.

The two selected scenarios are the WNA nuclear century outlook high 2008 and the IAEA 2012 high projection. The basic assumption of the selected scenarios can briefly be described as follow:

- WNA nuclear century outlook high (2008): The Outlook is built on a country by country assessment of the growth potential of nuclear power programs. The population of the countries are the key factor, on which the estimation on needed energy and nuclear capability are based on. The high trajectory assumes a full policy commitment to nuclear power. It assumes that fuel availability will not be a constraint for the growth of nuclear power. The estimated installed nuclear capacity in the year 2030 equals 1350 GWe installed (Gufler, 2013; WNA, 2008).
- IAEA 2012 high: The projection was based on national projections supplied by each country for a OECD/NEA study, indicators of development published by the World Bank, global and regional energy, electricity and nuclear power projections made by other international organizations and conclude with 740 GWe installed in 2030 (IAEA, 2012).

3. Proliferation

Several studies and publications, e.g. the INPRO project of the IAEA and a study carried out by the Brookhaven National Laboratory made a distinction between intrinsic and extrinsic designs features and measures to enhance proliferation resistance (Bari et al., 2009; IAEA, 2008).

Intrinsic proliferation resistance features of the system include physical and engineering aspects, extrinsic features institutional aspects as external barriers and safeguards. A combination of intrinsic and extrinsic features enhance the proliferation resistance (Bari et al., 2009).

The spread of nuclear power leads to a spread of fissile and fertile material and the technology of nuclear material handling. Of special concern is the enrichment technology, as it gives the owner the opportunity to enrich uranium to a weapon grade level. Gas centrifuges (state of the art technology) consume much less energy compared to (old) diffusion enrichment technology, which makes the detection of facilities much harder, compared to the diffusion technology. The reconfiguration of the cascades allows the owner of the facility to produce weapon grade uranium. The intrinsic proliferation risk is high, due to a relatively easy option to switch from a civilian to a military use. Especially extrinsic measures are needed to reduce the proliferation risk of enrichment facilities – i.e. safeguards. Also the mass balance gives indication if the facility is used only for civilian proposes. Another step in the nuclear fuel cycle which is of special concern is the reprocessing of nuclear fuel, with the option to separate plutonium. The handling of the material is more difficult, and there is the need for an enhanced technology. However this step was not analyzed in the paper (Kessides and Wade, 2011; Knapp et al., 2010).

4. Results

Several countries intend to introduce nuclear power into their energy portfolio. For the IAEA high scenario until 2030 the following countries can be listed as upcoming nuclear power producing countries, based on the presented positions on IAEA conferences and on the statements on IAEA Technical Meetings: Algeria, UAE, Malaysia, Vietnam, Belarus, Nigeria, Poland, Ghana, Indonesia, Bangladesh, Turkey, Saudi Arabia, Jordan, Niger, Egypt, Kazakhstan, Kenia, Thailand (IAEA, 2014c, 2013).

This would lead to a shift of the global nuclear industry towards developing countries and emerging markets. Additionally to the newcomer states the existing nuclear power using countries will enlarge their nuclear generation capacity. The main drivers on a global level are going to be China, the Russian Federation and India, while the growth in Europe and North America will be much weaker. The current situation of the global nuclear fuel cycle demonstrates clearly that the main capacities (conversion, enrichment and spent fuel reprocessing) are located in the slow growing regions, while the strong growing regions have a need to catch up.

The WNA nuclear century outlook projects a very strong growth of installed nuclear capacity until 2030. The growth is driven by the expansion of the nuclear power reactor fleet of existing nuclear countries, with several newcomers entering the market. The expected newcomers are Belarus, Egypt, the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates), Indonesia, Kazakhstan, Nigeria, Poland, Turkey, Vietnam, Italy, Jordan, Thailand, Philippines, Albania, Algeria, Australia, Austria, Bangladesh, Chile, Croatia, Denmark, Greece, Iraq, Ireland, Israel, Kenya, Malaysia, Singapore, Morocco, New Zealand, Norway, Portugal, Serbia, Syria, and Venezuela (WNA, 2008).

By comparing the IAEA high and the WNA nuclear century outlook it becomes clear that the amount of newcomer states varies strongly, which can be explained by the different approach and idea behind the projections. In order to gain results for the needed enrichment capacity the recent development of the capacity were taken into account and future developments were calculated in order to meet the demand of the future nuclear power reactor fleet. It was assumed that for 1 GWe of installed capacity 120 t of Separative Work Unit (SWU) are required per year. Additionally it was assumed that the capacity factor of the enrichment plants will be at 70% per year, corresponding to the operational history of enrichments plants. Based on the history of existing enrichment plants it was assumed that it takes up to five year until the plant reaches the full design capacity.

In order to meet the fuel requirements of the IAEA 2012 high scenario the enrichment capacity needs to be enlarged from about 68 kt SWU in the year 2011 to 127 kt SWU in the year 2030. As the enrichment plant in George Besse I was shut down in the year 2012, having had a capacity of 10,8 kt SWU per year, additional 67,5 kt SWU capacity are needed to be added on a global level – assuming that all existing enrichment facilities would continue operation till 2030 and no facilitates would have to be replaced. Taking the most recently built enrichment facility George Besse II with a capacity of 7,5 kt SWU per year as benchmark, this implies that up to 9 new enrichment facilities are needed to meet the demand (IAEA, 2014b).

In case of the WNA 2008 outlook due to the big amount of newcomer states and the strong commitment of existing nuclear states to expand their nuclear power programs would lead to the need of 231 kt SWU installed capacity. Such a capacity could be reached by adding about 170 kt SWU installed capacity. This means that around 23 new enrichment facilities would be needed until 2030.

The average design capacity of commercial enrichment facilities in operation on a global level is about 4 kt SWU per year, and the median value is at 4 kt SWU per year. The smaller design capacities would clearly enhance the number of enrichment facilities to be built. Several countries have even smaller enrichment facilities like the Chinese installation at Lanzhou with a design capacity of 500t SWU per year (Arnold and Gufler, 2014).

5. CONCLUSIONS

In order to guarantee a sustainable growth of nuclear power, investments into the nuclear fuel cycle are required. Regarding the proliferation threat, the enrichment is of special concern. There are several approaches to be taken into account when it comes to develop the nuclear fuel cycle in a proper direction. The concerns of many countries over spreading dual use technology was clearly demonstrated in the case of the Islamic Republic of Iran. Especially the technology of enrichment could be used not only for civil but also for military purposes. When taking into account that in case of a nuclear growth scenario a huge amount of new enrichment facilities would be needed to sustain the growth, more and more countries may aim to develop an almost complete domestic nuclear fuel cycle in order to assure the security of supply. Such a development would enhance the proliferation risk and the spread of nuclear material around the world.

This leads to the need to look into different options currently discussed.

The first option would be that every country is allowed to possess and develop a domestic nuclear fuel cycle including the enrichment technology. This is in accordance with the IAEA that assures every member state the same rights and obligations. Nevertheless the nuclear material should be safeguarded by the IAEA in order to reduce the spread of nuclear material. In such a case the safeguard mission by the IAEA would be huge, due to the high number of potential new facilities. This way does not seem to be feasible, due to the enormous workload and would lead to an enhanced proliferation risk, because nuclear material would be heavily spread –as well as the technology. In order to reduce the intrinsic proliferation risk, a step backwards towards the diffusion technology would help to monitor the enrichment facilities, as they can be hidden much more difficultly due to the high energy consumption.

The second option can be described as a black box option. This black box option includes a centralized enrichment and nuclear fuel bank organized by the IAEA and hosted by one or more member countries. The enrichment and the fuel fabrication would take place at those facilities. This could be an option if all countries would agree on such a solution. If only certain countries would obtain their fuel from such a facility this would enhance the imbalance between the IAEA member states. The spread of dual use technology would be reduced and the mass flow of fissile and fertile material could be more easily followed. The proliferation risk would be lower compared to the first option, but other negative impacts are not negligible. For certain countries the security of supply – one of the very strong arguments to introduce nuclear energy – could not be enhanced, but rather the dependency on certain supplier countries would be increased. The IAEA would need to make sure, that every country is going to be supplied with nuclear fuel on the same basis. If there is a threat for one or more countries, that due to certain boundary conditions nuclear fuel will not be delivered, they will not agree on this option.

There is a clear correlation between nuclear growth and an emerging nuclear proliferation risk. The emerging nuclear proliferation risk is driven by the need of more enrichment facilities, the spread of knowledge, and the spread of nuclear material. In order to tackle the emerging nuclear proliferation risk intrinsic and extrinsic features are needed, such as more proliferation resistant technologies in the nuclear fuel cycle and enhanced IAEA safeguards. The safeguards need to get more funding's and more competences in order to be able to fulfill their mission.

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