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Nuclear Commerce Markets and the Future Potentials

Abstract. *In an ever evolving and expanding world, there is a constant quest for both more energy and less external energy dependency. With the fossil fuels bound industry setting an alarming trend of negative ecological footprint, there is a clear and urgent must to predict and instruct on alternatives. And, this is the main purpose of this paper. As our key points of argument will show, there is no alternative decarbonized, greener primary energy mix possible in the future without the considerable share reserved for nuclear power. To this end, the development of nuclear power can only be achieved within the current legal framework of nuclear commerce regime. Consequently, we will rethink and revisit some of the fundamentals: the genesis of the world of atoms, applied nuclear science, its military and geopolitical implications, the nuclear commerce regime, legal framework behind this field as well as the factors speeding up or hindering the process of a renewed nuclear power generation, which can be tentatively named a nuclear renaissance. Hopefully, this process will lead to a safe, cleaner, cheaper and decarbonized, greener energy mix in the near future.*

Keywords: *Nuclear energy, PEM (Primary Energy Mix), NPT (Non- proliferation treaty), IAEA (Intl. Atomic Energy Agency), nuclear commerce, geopolitics of energy, security, legal framework, green growth, politico-military and security price.*

Since the first NPP in 1957, a lot concerning the nuclear market has changed, the most significant being opening the market to private businesses henceforth making the whole commerce procedure smoother and of lower economic price. It remains to be seen if the increased number of non-state commerce subjects are to lower or heighten the safety, politico-military and security price of it.

As a result of the oil embargo on the US, western Europe and Japan, imposed by OPEC (Organization of the Petroleum Exporting Countries), the opportunity for nuclear power expansion was tremendous to be set free from their dependence on oil. In theory, there has been a huge capability for nuclear power leading up to today, and the reason it struggled is due to all the legal and political barriers as well as very strong lack in public support. (Except France with a nuclear energy supply rate of 75–80%). At the end of the day a lot of it comes down to economics

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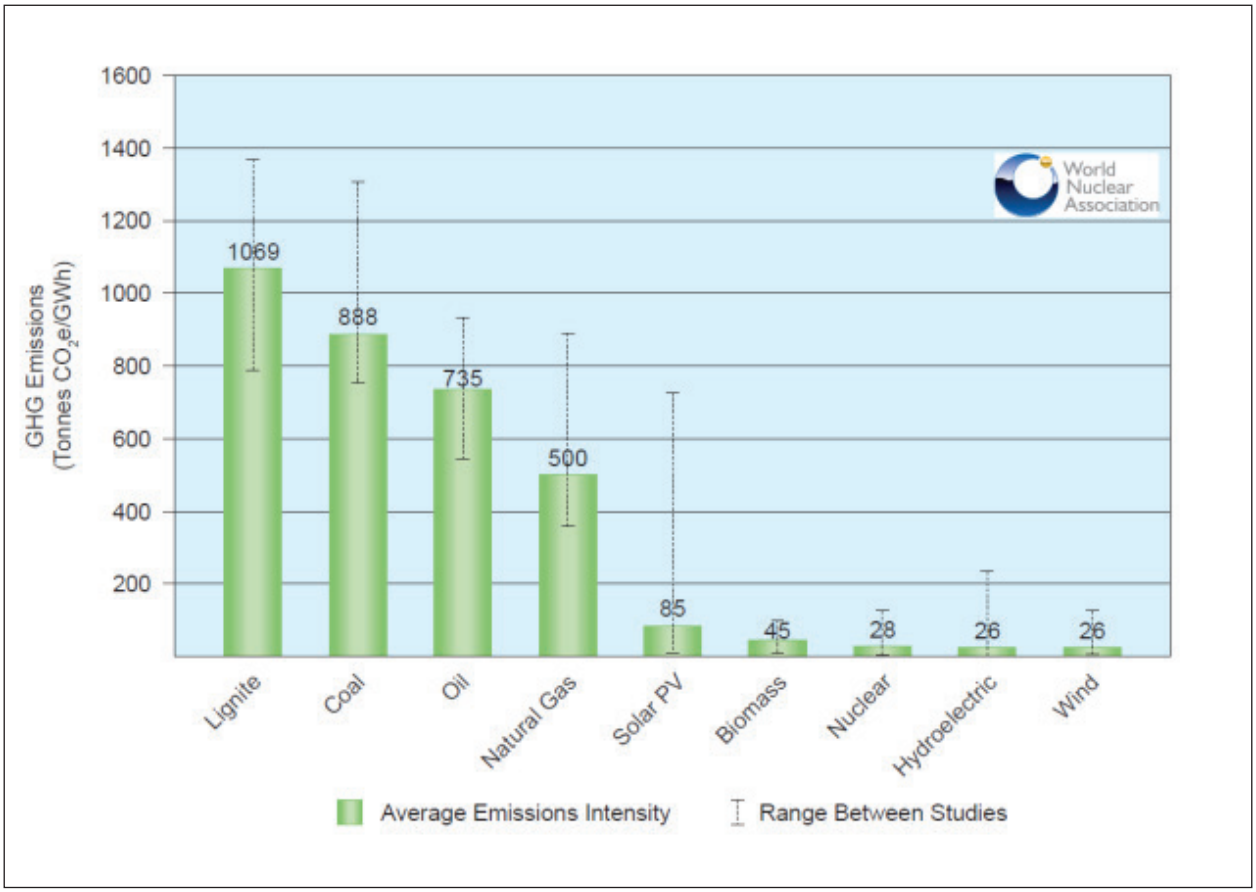

and sustainability. In other words; which methods are most cost efficient and least damaging?

Reasons for why nuclear power is an attractive source of energy can be explained by four main points of argument:

- It offers a stable supply of energy in times where the demand is increasing and other alternatives are not developed enough or too expensive.
- The NPP today are Generation III power plants and the new reactors have evolved tremendously, with larger capacities, (even) lower failure rates and the economic figures are constantly improving.
- Its increased momentum for business.
- Classed as a green energy, i.e. provides energy without interfering with climate change, as shown in the fig. 1, displaying greenhouse gas emissions by electricity generation.

Obviously building a nuclear power plant is a huge project and requires large sums of money which have to be invested upfront, while carrying a risk for 30–60 years. Once done, the plant requires operation/maintenance costs as well as nuclear fuel cycle costs (Uranium), however a large portion of the price set by NPP together with energy companies are to large extents made up from the decommissioning expenses as well as the future plant shutdown price.

The danger that a NPP is linked with is an obvious but very important fact, especially concerning professionalism of on-site workers as well as inspection professionals. Reservations regarding nuclear power have their focus on the threat of a nuclear accident, insurance cover and decommissioning of outdated NPPs and waste management. The result of the tsunami in Japan (Feb. 2011), which severely damaged the Fukushima power plant, occurred at a very sensitive mo-

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ment of time for nuclear development and its industry. At a point when nuclear power was entering a "renaissance" and had upheld many trouble free years, a rain of negative media hit the industry. Many of us started questioning nuclear power (once again) and the incident also startled East Asian and South-East Asian countries which are located in the same earthquake troubled zones. However, they have not interfered with current nuclear projects (a total of 110 which are planned/under construction[1]) because of the setback in Fukushima:

- In Japan, the new government is re-evaluating the decision of their predecessor on phasing out the nuclear programme,
- Chinese government announced the replacement of the planned Generation II reactors with the improved Generation III reactors, which will meet the safety requirements but slow down nuclear expansion in the country due to higher costs,
- India has affirmed plans for boosting the nuclear capacity by 2032,
- Taiwan, South Korea and Vietnam are proceeding with their announced plans,
- Malaysia is considering the option for nuclear power,
- Thailand and Indonesia have delayed their nuclear programmes, but most likely because of high costs.

Although the long-term impact of the Fukushima disaster on the nuclear programs is not yet clear, the predictable consequence is likely to be the rise in costs due to more rigorous safety requirements and an increase in finance costs, reflecting lenders' reassessment of the commercial risks.[2]

The Nuclear Commodity Market

According to the World Nuclear Association (WNA), the commercial worldwide demand for uranium is around 68 500 tons of uranium per year[3].To simplify this, one must understand that USA (with its 104 NPPs) has a demand of 18 816 tons per year, which corresponds to about 28% of the world market[4]. Again it is the OECD with the NEA which provides account of the Uranium reserves in the form of their so called Red Book, a biennial report on uranium reserves. Canada, who has been by far the biggest supplier with some 11,500 tons of U-3O8 per year until 2009, has been replaced by Kazakhstan that produced a staggering 21 300 tons in 2012. Both countries are followed by Australia, Nigeria and Namibia.[5] The table is surprising, considering that Australia holds the largest known recoverable resources of Uranium, 31%. Also worth mentioning is that among uranium-exporting countries, Australia and Canada have some of the strictest conditions relating to the use of its uranium. These safeguards (inspections and accounting procedures) ensure that exported uranium is used for peaceful purposes only and is not diverted for military purposes or used in a way which adds to the proliferation of nuclear weapons. This tells us that there is a possibility for a nuclear commerce framework that serves as an efficient non- proliferation tool.

Further on, United States as well as China and India rely mainly on imports, thereby neglecting any more extensive domestic production.

As for the companies engaged in this field, it was again the 1990's that brought movement into the market. Cancelled nuclear energy related projects paired with low uranium price pushed profits down to a level that made any new involvement quite unattractive. The consequence was a

[1] WNA — 2010

[2] Report from the Centre for nuclear non- proliferation and disarmament 2013

[3] World nuclear Association 2012

[4] NEA (2010), p.6, World Nuclear Association 2014

[5] Stockinterview.com (2006); p. 96, World Nuclear Association 2014

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takeover and consolidation wave, leaving 8 different enterprises with a combined world share of 81 percent[1]. The big three, namely Cameco (15%), KazAtomProm (15%) and Areva (14%) alone make up for half of the worldwide extraction[2].

Although the nuclear industry has a steady supply of uranium resources, companies have been relying on current mine sites and current resources. The demand for uranium has in no way been a linear curve throughout time. During post WWII times as well as during the cold war excavation rocketed, and for the time in between and after we notice a remarkable decrease. The first available option for the nuclear market would be to increase the number of existing mines. This is crucial if we seek a rise in nuclear power in this century. However, this also poses a problem for investors wanting to partake in nuclear power due to the long time-lapse of twenty years from the day of discovery to the start of production.[3] However, searching for uranium is in a way much easier than for other mineral resources because of the radiation signature from uranium`s decay products that makes these deposits identifiable from the air. The second option would be to extract the huge amounts of enriched uranium and plutonium stocks from nuclear warheads, which is not an easy task. Nevertheless, a major secondary supply of uranium is already provided by the decommissioning of nuclear warheads by the USA and Russia. Since 2000, 13% of global uranium requirement has been provided by this ex-military material[4].

In the years 2005–2007 the world witnessed a uranium price bubble taking place. This coincided with significant rises of stock price of uranium mining and exploration companies. Luckily for the nuclear commerce and its market the price per pound for uranium stabilized to a fairly "normal" price in 2010.

Thorium is a possible alternative source of nuclear fuel, but the technology for exploiting it is not yet established. Thorium requires conversion to a fissile isotope of uranium in a nuclear reactor. However,

[1] WNA (2007), n.p.a.

[2] UNFC (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources) 2013

[3] Stockinterview.com (2006), p.128

[4] World Nuclear Association 2012

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supplies of thorium are abundant, and the element currently has no commercial value. Accordingly, the amount of resource is estimated rather than directly measured, as with uranium. And although the benefits of thorium often appear overstated, there seems to be some great theoretical advantages regarding primarily sustainability, reducing radiotoxicity and reducing proliferation risk. The greatest interest for developing thorium fuel cycle is visible in India and China; India has major thorium reserves and the possible use of thorium reactors has been under discussion there for decades now. However, the Indian estimate is that about two decades of research and development are needed to assess the performance of thorium reactors, before replicating the initial prototype. China`s interest in thorium is quite new, but nevertheless has started a substantial research programme on the subject. In January 2013, there were 150 PhD scientist already working on the project. Because of the vast thorium reserves, China has a possibility of powering their electricity on thorium basis for generations to come, given the results in the field prove promising[1].

The complexity and gravity of an industry like atomic power is seldom left entirely to a free and liberalized market. Because of political frictions between the global superpowers, they have developed their own enterprises. Quite naturally, an international takeover in the reactor business is a very sensitive topic for most countries as it poses a question regarding national security.

While traditional theories argue that stiff competition generally provides for incentives to innovate, the sheer magnitude of nuclear projects and the strict legislative framework around it makes it very hard for smaller enterprises to enter the industry. The nuclear industry could definitely benefit from a more liberal market in terms of innovation and progress.

Nuclear Plant Construction- Fundamental Considerations

The sector of nuclear power plant construction is the most important area for future innovation and development, and it is also the area that has seen most changes within the nuclear industry over the years. Expertise in the industry is the key to success, and the demand for educated and professional engineers cannot be too high. The world has yet to see a nuclear power university, which could aid the industry tremendously. The current market leaders, which "dominate" the nuclear industry, are:

- AREVA — French/German
- Atomenergoprom- Russian
- Cameco- Canadian[2]

The biggest issue companies have to deal with when constructing a NPP, is that every new plant is treated as a completely new case. This makes the whole process a lot more time consuming and expensive as companies make their way through the bureaucratic jungle that surrounds this business.

There are plans for constructing Generation IV power plants, designed to offer higher levels of safety, economics, non-proliferation and sustainability than the current Generation III. An international cooperation framework, known as Generation IV international forum (GIF) has been set up to establish a platform for creating systems, identified as most promising. The generation IV systems are expected to enter into force in estimated 20 years.

Another innovation in the field is an idea for Small Modular Reactors; the adjective "small" standing for the electrical power input that should not exceed 300 MW, which is a significant decrease from

[1] World Nuclear Association 2014

[2] World Nuclear Report 2012

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Table 1.

Defence level	Objective	Essential means
Level I	Prevention of abnormal operation and of malfunction's	Conservative design and high quality of construction and of operation.
Level 2	Control of abnormal operation and detection of malfunctions.	Control, limitation and protection systems and other surveillance characteristics.
Level 3	Control of accidents included in the design basis.	Engineered safety systems and accident procedures,
Level 4	Control of the severe accident conditions of the plant, including the prevention of accident progression and mitigation of consequences.	Additional measures and accident management
Level 5	Mitigation of the radiological consequences of significant releases of radioactive products.	External site emergency plan.

large Generation III reactors currently used. Other advantages of Small Modular Reactors would include a high level of modularity in design and construction and the possibility to expand them with adding modules to generate even as much power as a larger reactor. Successful development of the Small Modular Reactors could attract new countries to the nuclear club, who do not need the size and/or do not have the means to finance the costs of conventional 1,000 MW and larger plants[1]. These ideas could prove very promising in a sense of making nuclear power more socio- economically suitable for the interested parties.

Nuclear Safety

Nuclear safety stands for the process of eliminating unintended conditions or events that lead up to radiological releases from the otherwise legal and authorized activities. Nuclear safety is closely linked to nuclear security and nuclear safeguards, although we have to distinguish the three:

- nuclear safety covers the activities aimed at preventing nuclear and radiation accidents or to limit their consequences in the management and activities of nuclear power plants, other nuclear facilities, transportation of nuclear materials and the use/storage of nuclear materials for uses in the fields of medicine, power, industry and military (although the oversight on military nuclear programs is usually executed by different agencies than those operating in civilian sector),
- nuclear security stands for preventing international misuse of nuclear and other radioactive materials by non-state actors to cause harm, mainly by enhancing security at the nuclear power plants and in the process of transportation of this materials,
- nuclear safeguards are focused on restraining the activities of (primarily, but not exclusively) rogue states that could lead up to acquisition of nuclear weapons[2].

The most extensive fields to cover when it comes to nuclear safety are without a doubt the safety of nuclear power plants and the safe management of nuclear waste material. This importance also results in the fact that these two issues are the most politicized themes in the nuclear safety field. When it comes to power plants, statistics show that only three major nuclear accidents happened in over 15 000 cumulative reactor years in 33 countries, concluding that nuclear power plants are a safe way to produce electricity. In the tab. 1, five- level approach to maintaining safety at a nuclear power plants is shown.[3]

[1] OECD 2012

[2] World Nuclear Association 2014, Petrangeli (2006).

[3] Petrangeli (2006), p.90.

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Unfortunately, like in the aviation industry, there can be a lot of bad publicity regarding nuclear safety and its accidents, and not enough evidence- based facts and conclusions. This was also visible in the latest nuclear power plant disaster in Japan. The authors of a book on the subject, Fukushima: the story of a nuclear disaster, sum up this matter very well by saying: "There are lessons to be learnt from what went wrong at Fukushima. There are equally important lessons to be learnt from what went right[1]".

An auditor for global nuclear safety is the IAEA, which prescribes safety procedures and has since obtaining this role established a system of reporting even the most minor accidents that occur. State safety inspectorates for nuclear power plants also work very closely with the agency and these activities only enhance the importance of the role that the IAEA has today.

In the nuclear safety field, there is also a great and important role reserved for state and non- state actors on a national level. State and local governments, local watchdog groups, concerned citizens and the media all play a significant role in obtaining, enhancing and maintaining nuclear safety.

An additional important aspect of nuclear safety is the human factor, therefore the relationship and mismatch between human and technology. The human factor analysis offers an insight into human capabilities, characteristics, limitations, behavior patterns and motivation. In nuclear safety the human factor can be visible on the macro-level, with the wrong decision- making process at the time of nuclear accidents but also on the micro- level in reduced productivity and the on-site demeanor that endangers employees' health. As a result of such crucial importance to adhere to safety procedures and protocols, there is an emphasis on the human factor in design, operation, maintenance and decommissioning of nuclear power plants. In this aspect, proper training and substantial safety culture of employees is essential, if we are to expect the technological measures in securing the nuclear power plant to work as anticipated[2].

Another key part of nuclear safety, the legal framework behind it, started to gain momentum after the Chernobyl accident in 1986 (in contrast to the Fukushima accident that left the world mum) when the nuclear industry and world governments realized that substantial steps will be needed to regain public trust in nuclear energy. This hastened a series of new legal documents and agreements, the most important being the Convention on Nuclear Safety that is a principal treaty on nuclear safety. It applies on nuclear power reactors and has 75 parties; most notably missing in the signatory parties is Iran (Egypt also, that plans to start its nuclear energy programme in the future). Complimentary to the Convention on Nuclear Safety are the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident. These two conventions have 114 parties, including all the states with nuclear power reactors and most of the states with any significant nuclear activities. As always, there are exceptions to the general rule: North Korea, Syria, Uzbekistan and Venezuela.

Another really important treaty on nuclear safety is the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. The convention and its provisions apply mainly on spent fuel and radioactive waste material from civilian nuclear reactors, their safe management and also trans- boundary movement. It has 64 parties although it is concerning that many states with operating nuclear power plant reactors are not parties

[1] Lochbaum/Lyman,/Stranahan (2014), p. 84

[2] Stanton (1996), p.5

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to the Convention, namingly Armenia, India, Iran, Mexico and Pakistan.

We need to consider nuclear safety (along with nuclear security and nuclear safeguards) as one of the main fields impacting the public trust in the nuclear energy. Hence, this makes it of highest importance for the established provisions to work. And as written before, citizens can also play a role in this process, helping to make small steps for the nuclear energy and its security, while also ensuring a big step for a brighter future of the whole planet.

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