Research and Development of Nuclear Science and Technology in Preparing the Nuclear Industry in Indonesia

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Abstract: The Geneva conference sponsored by the United Nation (UN) in 1955, "On the peaceful uses of atomic energy" was held to promote a nuclear energy utilization path only for civil or peaceful purposes. Nuclear energy is used in more than 30 countries and contributes 16% of global electricity consumption. Indonesia has been developing its own capability for nuclear science and technology since 1954 with the aim of having a nuclear industry in Indonesia. Indonesian's experiences of operating research reactors since 1965 for preparing a new era of nuclear industry in Indonesia can be used as a basis for science and technological capabilities for constructing its own nuclear industry. In relation to research and development (R&D) activities on nuclear science and engineering, Indonesia becomes the leading country on nuclear technology in South East Asia especially its operating experiences in nuclear research reactors. The nuclear industry, which is based on non electric application, has already been pursued such as for agriculture, medicine and hospital utilizations etc. In case of electric based utilization such as nuclear power plant (NPP), Indonesia has a plan for the first 2 NPPs to be constructed within 2010-2015 and this will be doubled by 2025 for fulfilling 4% of the nuclear electric share of the total national energy mix a long with other new and renewable energy sources.

Keywords: peaceful uses, nuclear energy, Indonesia, nuclear industry, energy mix.

1. Introduction

Nuclear energy as attracted many countries for use as a deadly weapon or mass destruction explosive from the beginning of nuclear reactor had been invented up to the end of world war two. In the beginning of nuclear technology application, nuclear energy was used for military purposes such as submarine (U.S "Nautilus") and followed by Russia and it continued by conducting nuclear weapon. Two deadly nuclear attacks were undertaken at Hiroshima and Nagasaki in Japan at the end of World War II. The Geneva conference which was sponsored by the United Nation (UN) in 1955, "On the peaceful uses of atomic energy" was held to promote a nuclear energy utilization path for civil or peaceful purposes only [1]. Those peaceful uses of nuclear energy are applied for irradiation of agriculture, farming, health, medicine, hospital, and industry. Water desalination, enhanced oil recovery, coal gasification and liquefaction as well as hydrogen production are some potential future applications of nuclear energy. Generating electricity from nuclear energy at nuclear power plant is more generally recognized and is used in more than 30 countries to about 16% of world electricity consumption. This paper will evaluate the nuclear program in Indonesia and propose some programs for implementing the nuclear industry in Indonesia. The first nuclear plant as for the peaceful use of nuclear technology application for generating electricity was started by Russian government in Obninsk on June 27, 1954 [2] to generate 30 MW and started as a massive program of NPP after Geneva conference. Up to 2006, more than 440 NPPs in the world have been constructed and operate in more than 30 countries. These contribute 370 GW of electricity or 16% of world electric demand. Those NPP which were commercialized around the world do not include a lot of nuclear reactor for research and development in research centers or national laboratories as well as industries and universities. Recently there are at least 27 new NPP which are under construction and this will be multiplied over the next few decades. At Paris ministerial conference, in March 2005, eight countries gave a positive signal for utilizing nuclear technology such as Morocco, Indonesia, Iran, Poland, Turkey, Bangladesh, Egypt and Vietnam and more than 30 other countries at the conference were interested in utilizing nuclear technology.

2. Nuclear Science and Technology in Indonesia

Indonesia is one country which is committed to use nuclear energy for its national energy utilization program and has been developing its own nuclear science and technology capability since 1954, the same period with the first NPP in the world was operated in Obninsk, Russia. This was followed by the establishment of the Lembaga Tenaga Atom (LTA), or Indonesia Atomic Agency, in 1958 and changed into Badan Tenaga Atom Nasional (BATAN) or National Nuclear Energy Agency (NNEA), in 1964. The idea for constructing NPP in Indonesia was released in 1968 and as a program action to prepare the readiness of Indonesian capability to build NPP, in 1972, Indonesia started some studies for introducing NPP and made an commission for preparation of NPP construction (KP2-PLTN, Komisi Persiapan Pembangunan-PLTN). Therefore, Indonesia has prepared a lot of activities in research and development of nuclear technology especially for NPP utilization which was started from the first research reactors in 1965, which was formally opened by the first president of Indonesia, Soekarno, in Bandung. After obtaining some experiences from the first research reactor and requiring some additional facilities for research and development programs, in 1979 with the same year when Three Mile Island (TMI) accident happened, Indonesia constructed its second research reactor in Yogyakarta. This reactor was called home made reactor because of the design and construction processes were performed by Indonesian scientists and engineers with the help of General Atomic's (GA) supervision. In 1987 or one years after Chernobyl accident in Ukraine (former Soviet Union), the third research reactor (G.A Swabesy) was established with relatively high power generating for a research reactor.

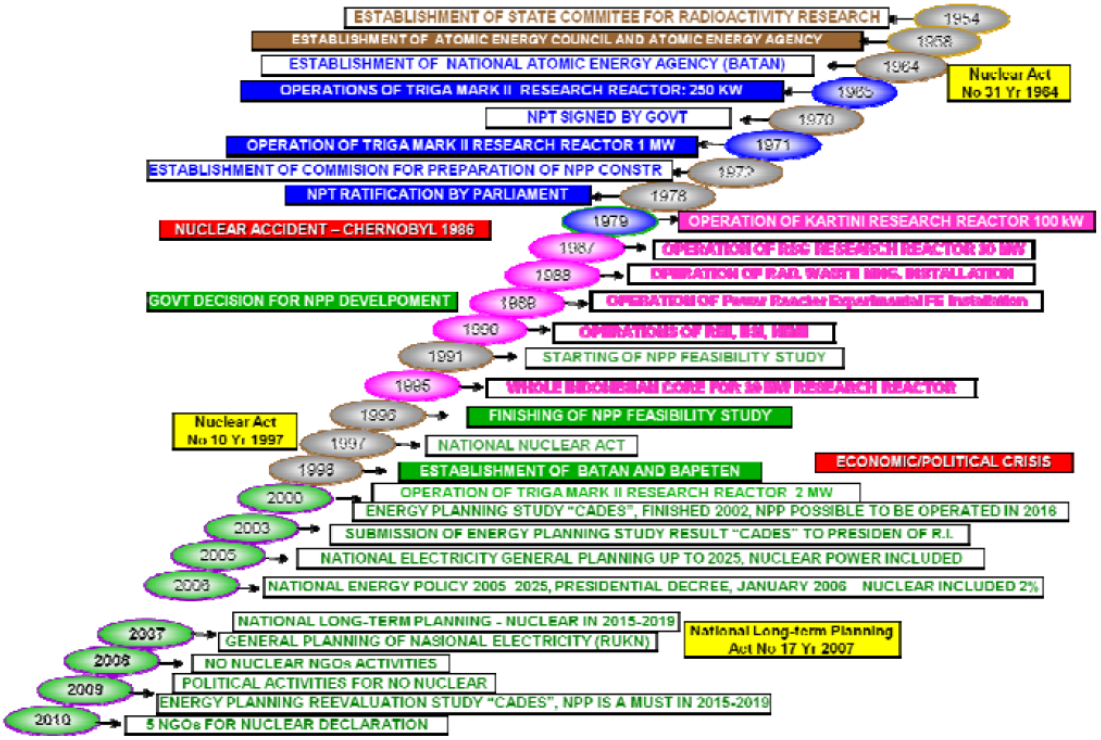


Figure 1. History of Research and Development of Nuclear Science and Technology in Indonesia [3].

Table 1. Energy Resources in Indonesia Fossil Energy (ESDM, 2004) [5].

Fosil Energy	Resource	Reserve (Proven + Possible)	Annual Production	Ratio Reserve/Production (without exploration) (year)
Oil	86.9 Billion Barrel	9 Billion barrel	500 Million Barrel	18
Gas	384,7 TSCF	182 TSCF	3.0TSCF	61
Coal	57 Billion ton	19,3 Billion ton	130 Million ton	147

In case of electric based utilization such as nuclear power plant (NPP), Indonesia until now, does not have any NPP since the program for introducing NPP (KP2-PLTN) was released almost 40 years ago. In relation to research and development (R&D) activities in nuclear science and engineering, Indonesia has become the leading country for nuclear technology in South East Asia especially its operating experiences in nuclear research reactors. It has several plans for constructing the first NPPs since 1980s, however, it was postponed up to the end of 1990s and more additional delayed time up to now. Recent Indonesia energy program, NPP program has been included in Indonesia energy program to be implemented and it will be constructed within 2010-2015 and it will be doubled in up to 2025 to the total national energy mix scenario as well as electric share from others new and renewable energy sources [4]. Indonesia has a similar starting point with other Asian countries in R&D activities and nuclear programs for non-energy activities. However, in order to implement the nuclear programs for generating electricity application, it has some obstacles such as some political issues and economy crisis [5]. In recent time period some pro- and anti-nuclear activities have happened such as anti-nuclear activities protesters during 2008 and some NGOs who pro-nuclear made a declaration "go nuclear" recently in 2010. As with other countries, conducting a nuclear program is not just a matter of technical or economical capability but also requires public acceptance and dealing with some anti-nuclear organizations as well as policy making within government and parliament. The whole picture of nuclear science and technology in Indonesia can be seen as timeline from 1954 up to now as shown in Fig. 1.

3. Energy Resources in Indonesia

Indonesia has enough resources such as oil and gas, coal and hydro to develop its own economic growth for decades. However, those natural resources will be exhausted and they will be quickly exhausted when rapid consumption rates happen without any additional exploration or mining. Indonesian residents and industries will always face a cut of electric supply or an irregular supply based on the regulation in each area. As shown in Table 1 [5], fossil fuel based energy will be remaining Gas and Coal after next 20 years and no more oil for generating electricity as well as for transportation if there are no more reserves are founded. However, about 70% percent of Indonesian coal resource exported so that only 30% remains for national utilization [6]; therefore Indonesian coal resource will last no more than 100 years.

Other resources as shown in Table 2 can be utilized for replacing fossil resources which are declining at the same time energy demands are increasing rapidly. Those resources have been called new energy and renewable energy resources. How to maintain the remaining resources from fossil fuels and gaining new fuel and renewable fuel to fulfill national energy demand optimally, it requires a systematic and effectives way, not only from some resource based approaches, but also some technological capability approaches. Technological approaches mainly come from ideas to utilize some new and renewable energy resources. Because without any technical support capability, those non-fossil fuels are only a potential capacity, not usable capacity. Therefore, research and development related to those new fuel resources should be emphasized as well as low technology utilization for some of well established sources.

Table 2. Energy Resources in Indonesia non fossil Energy (ESDM, 2004) [2,5].

Non-Fosil Energy	Resource	Installed Capacity
Hydro	75,670 MWe	4,200 MW
Geothermal	28,170 MWe	1,189 MW
Mini/Micro Hydro	500 MWe	86.1 MW
Biomass	49,810 MWe	445 MW
Solar	4.8 kWh/m2/day	12.1 MW
Wind	9,290 MWe	1.1 MW
Uranium *	34,112 ton (e.q. 1000 MWe for 170 years)	
Thorium **	1,500 ton (e.q. 100 MWe for 75 years)	

* Source: BATAN, 2009. Uranium utilization is calculated based on uranium resources in Kalan, Kalimantan (West Kalimantan) 24,112 ton and Kawat (East Kalimantan) 10,000 ton. There are several areas where indicated have a potential of Uranium resources such as Papua.
** Thorium, from estimated area based on alluvial Thorium in Bangka Belitung

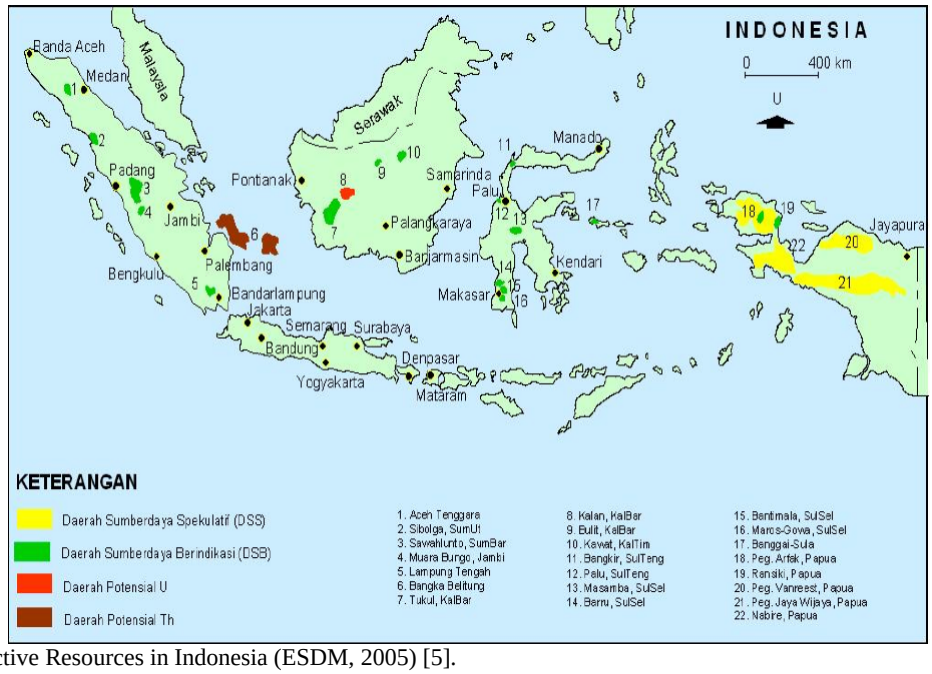


Figure 2. Radioactive Resources in Indonesia (ESDM, 2005) [5].

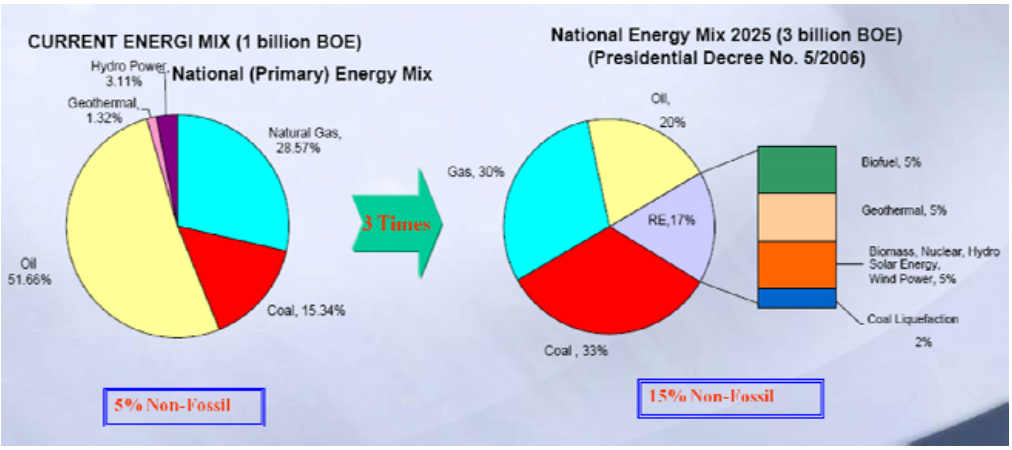
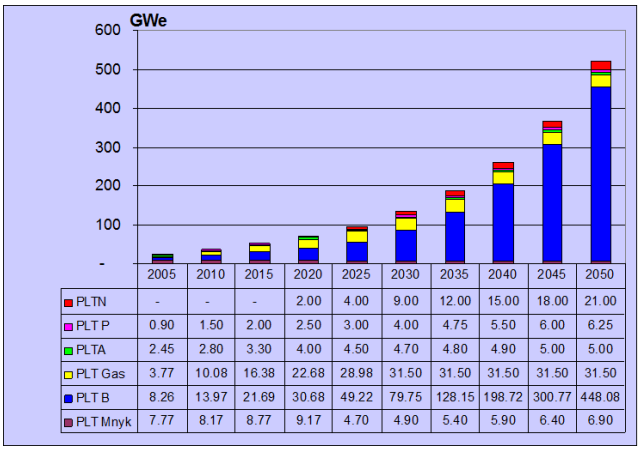


Figure 3. National Energy Mix in Indonesia (President Act, 2006) [7].

Based on uranium resources, NPP in Indonesian can be constructed using its own fuel resources. If Indonesia want to use their own resources by adopting a once through fuel utilization system, two sites in Kalimantan can provide 170 years for a single 1 GWe NPP class and additional Thorium resources can be used for 75 years NPP utilization. A once through fuel cycle system means fuels are used once and all spent fuel cannot be used again. By recycling processes some 95-97% spent fuel can be reprocessed and recycled as a new fuel such as mixed oxide (MOX) fuel based on uranium and plutonium recovery. This recycling option can allows uranium to be utilized much longer. Some other radioactive resources in Indonesia shown in Fig. 2.

To optimize all fuel resources in a National Energy Mix in Indonesia, president initiated to make a government act to provide effective and rational energy sharing based on resource potency and technical capability as well as economic and environmental issues. As shown in Fig. 3, Indonesia is planning to reach 17% energy share from new and renewable energy utilization up to 2025 and nuclear contribution is included with

other resources such as biomass, hydro, solar energy and wind energy which about 5% in total energy mix. By 2025, NPP contributes 4 GW of electrical share and it will be 21 GWe in 2050 as shown in Fig. 4, to accommodate increasing energy demand and reducing CO_2 emission which is mainly coming from fossil fuel. It was estimated 478 million ton of CO_2 emission will be released in 2025 and 3,322 million ton in 2050.



	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
PLTN	-	-	-	2.00	4.00	9.00	12.00	15.00	18.00	21.00
PLT P	0.90	1.50	2.00	2.50	3.00	4.00	4.75	5.50	6.00	6.25
PLTA	2.45	2.80	3.30	4.00	4.50	4.70	4.80	4.90	5.00	5.00
PLT Gas	3.77	10.08	16.38	22.68	28.98	31.50	31.50	31.50	31.50	31.50
PLT B	8.26	13.97	21.69	30.68	49.22	79.75	128.15	198.72	300.77	448.08
PLT Mnyk	7.77	8.17	8.77	9.17	4.70	4.90	5.40	5.90	6.40	6.90

Figure 4. Power Plant Projection in Jamali Connection 2005-2050 [3].

4. Nuclear Energy Utilization Program in Indonesia and Asia

In general nuclear energy has been introduced to be applied in various technical fields and applications which can be categorized as non-energy utilization and energy utilization. Non-energy utilization can be classified as utilization of nuclear radiation from radioisotopes or neutron applications. In the case of energy utilization, this is the basic nuclear application for electricity such as nuclear power plant (NPP), desalination, hydrogen production and so on which are powered by the excess heat produced from the reactors. These features of nuclear science and technology applications can be applied as multi-purposes technology utilization. A single technology can be used for more applications and benefits such as from one NPP can be applied for generating electricity and in the same time, some excess heat can be used for desalination process and hydrogen production. Those nuclear energy applications are being or will be conducted by BATAN or NNEA National Nuclear Energy Agency in cooperation with some radiation facilities which are related to industries, medical facilities, farming, so on. As a country committed to a nuclear program as a part of its national energy program, Indonesia with other Asian countries has started its own R&D activities and nuclear programs for non-energy activities and preparing nuclear programs for generating electricity application (NPP) as shown in Fig 5. Japan as well as India have their R&D in nuclear science and technology program and after importing some NPP from countries such as USA, Canada or UK, they started to learn much more about NPP as well as their capability of basic R&D in nuclear science and technology. To start their Nuclear Industry, Japan as well as India needs about 10 years and require additional 10 years for producing their own technology after buying a license from established nuclear manufacturer. Korean started their R&D in nuclear development later than Japan and India and also from Indonesia. However, they can improve their capability and pursuing their nuclear industry for commercial NPP after 20 years experience in Nuclear R&D. Brazil has similar conditions with Korean for obtaining commercialized NPP after 20 years experiences in research reactors. China had a longer period for conducting commercialized NPP; about 30 years from starting the first research reactor. In the UEA, R&D program is the shortest time or maybe does not have any reactor research facilities, but they are willing to construct some NPPs, even though they still have a lot of oil resources. Indonesia has a long experience in conducting R&D in Nuclear program; however, up to now no NPP has been constructed; only some postponed planning. The first NPP plan was released almost same period with Korean at 1980s [8], however, it was postponed, and up to now. Hopefully, with strong leadership and a commitment

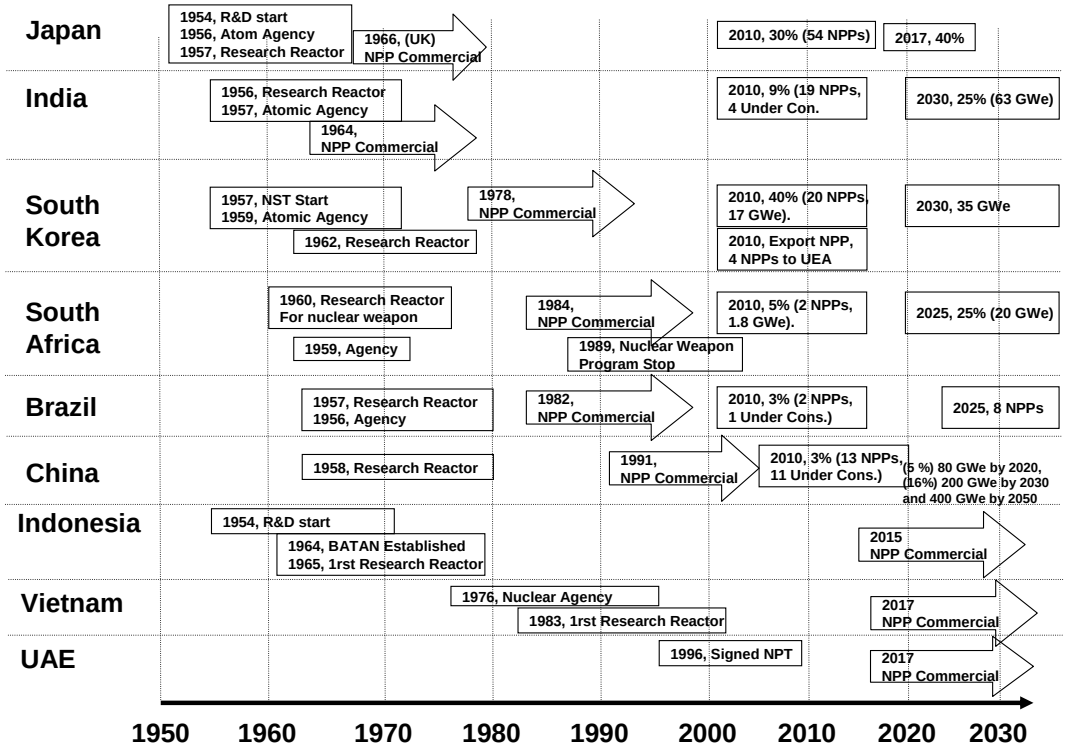


Figure 5. Research and Development on Nuclear Science and Technology in Asia.

to the government blue print of energy, NPP can be constructed soon. As stated by the ministry of research and technology in their National Research Agenda, 7 focused areas will be the priority to be conducted for developing national science and technology achievement. Those focused areas are (1) food security, (2) energy, (3) Information and communication technology, (4) technology and management for transportation, (5) defense and security technology, (6) health technology and drugs, (7) Advanced material to support technological development in each focused area. Those fields should be integrated by two supporting success factors, basic science factor and social humanity factor (ARN, 2010) [9]. In the energy sector, there are 3 research group themes; (1) research on improvement of the national electrification, (2) research on new energy and renewable energy resources, (3) research on energy conservation. Energy sector becomes one of the priorities, not only because of the resources aspect as well as economy and environmental issues, but also to pursue an innovative technology based approach. It brings all Indonesia human resources more focused on priority sectors especially the energy sector as well as bringing government mind set to not only dealing with the energy program based on some resource approaches, but also diversifications and multipurpose approaches of energy based on technological capability, research and development experiences.

5. Challenges of the Nuclear Industry in Indonesia

It is already known that stability and sustainability on the fuel supply for generating electricity or other energy applications will become a crucial issue. In addition, transmission and distribution of electricity or energy from the power plant to residents or industries and other consumers should be well planned. In the case of nuclear energy utilization, fuel loading is arranged yearly and its nuclear power plant (NPP) will operate continuously for up to 40 to 60 years. There are several scenarios for sustaining fuel supply which will be optimized in regards to fuel resources and technological capability in Indonesia as well as economic and fuel independent supply issues. Derivative technologies from fuel management field such handling and fuel fabrication technologies, fuel reprocessing and discharging technologies, fuel partitions and transmutation technology, and some other related fields. In the case of constructing NPP, some integrated technologies will emerge such as mechanical field, material, electrical, geological field, and reactor physics. Public participation and public acceptance in arranging regulation of reactor operations should be managed carefully as well as economic impact because of constructing the NPP near by the local society such as infrastructure transportation, employee, and incentive for the people who live near to NPP facilities, and so on.

NPP as a well commercialized product in the world for more than 60 years as a mature technology should be involved in a business scheme in Indonesia, not in a R&D stage of technology, but NPP should be under the framework of business and industry. Therefore, the status of NPP is not in a level of R&D stage which is undertaken by the ministry of national education and the ministry of research and technology. NPP program should be in line with the ministry of trade and industry as well as the ministry of energy and natural resources, and some companies should be involved in this NPP scheme. Furthermore, it can establish a new era of nuclear industry in Indonesia for non-electrical and electrical based utilization. One of the lacks of synergy in Indonesia is that research and development side such in research center or university do not match with the industry. Therefore, nuclear industry should be initiated by government by accommodating all stake holders who commit and are interested on NPP program nuclear industry in Indonesia. There are three basic institutions which give a strong program for nuclear industry such as regulatory side, industry side and research and development side from research center and universities. Regulatory side is government or coordinative local government. Those stakeholders can solve some of the issues for introducing NPP such as how to make a synergy in organizing a consortium of NPP for instance, to solve the economical aspect related to investment whether government provides a credit for NPP or investment from private company or government or a consortium. Infrastructures readiness should be emphasized according to international standard infrastructures. According to basic infrastructure for a nuclear power project made by the IAEA [10], there are 19 aspect which have to be fulfilled by the government who want to implement a NPP program, including: 1 National Position, 2. Nuclear safety, 3. Management, 4. Funding and financing, 5. Legislative framework, 6. Safeguards, 7. Regulatory framework, 8. Radiation protection, 9. Electrical grid, 10. Human resources development, 11. Stakeholder involvement, 12. Site and supporting facilities, 13. Environmental protection, 14. Emergency planning, 15. Security and Physical protection, 16. Nuclear fuel cycle, 17. Radioactive waste, 18. Industrial involvement, 19. Procurement.

Those aspects can be conducted with the synergy from all stakeholders, and a more important aspect is that public acceptance and public participation should be involved for all processes especially local government and local society or people in the area that NPP is located. Public trust and confident in all regulation will be the biggest challenging aspect. Public need a strong leaders and high confident in the regulation from the government. Nowadays many of local governments are interested in nuclear program and are conducting some agreements with research center to make a feasibility study to build a NPP in their area.

6. Turnkey Project and Self Capability Building

Present condition in Indonesia for constructing the first NPP will be limited to self-capability, regulation and social aspects as well as strong leadership from the government. Self-capability means, Indonesia should have their own capability to build the nuclear industry based on their existing R&D in research centers, universities, national or Indonesian private companies. A proven technology and well commercialized types of NPP are the keywords for the first NPP everywhere, especially in Indonesia. People pay particular attention to the safety of NPP, safety culture and some other negative issues of NPP. Based on those keywords, Indonesia does not have an opportunity to build their own NPP even though some part of reactor can be produced by the Indonesian based on their long history of R&D. Therefore, like it or not, Indonesia should buy the first NPP from foreign countries and even its second up to several NPPs. However, some analysts have worried about Indonesia's independency when using foreign imports for energy. Those aspects are some of the key aspects why turnkey project should be adopted. Some other benefits when Indonesia adopts a turnkey project include; Indonesia will use their own existing human resources, facilities and local industry as well as being a driving force to speed up the growth of some local industries. Indonesia can learn and extend their own capabilities from the initiation of NPP project and organize all R&D facilities. In addition, the human resource program and training center for operators and student who want to work in the nuclear industry should perform as a long term energy program. Based on a learning process of turnkey project in Japan, Korea and India, the average turnkey project of NPP is about 10 to 20 years form the first commercial NPP to take over all project or

major project of NPP by their own capabilities. If the implementation of the first NPP will be in 2015/2016, it can be estimated that the turnkey project should be finished around 2025 to 2035. Therefore, to move in more efficient and strong implications to all stakeholders in implementation of nuclear industry, a clear political statement for "go nuclear Indonesia now" from the president it strongly recommended. While in the same time the technical capability, social preparedness, economical aspect as well as human resource are well prepared. "Go nuclear" statement from the president, is recognized not only as a political symbol of the government, but also as an implementation of a mandate from the legislation of the law No. 10, year 1997 and No. 17, year 2007 about the basic law for nuclear energy implementation in Indonesia.

7. Conclusions

Indonesian's experiences at operating research reactors for preparing the nuclear industry in Indonesia and developing its own capability on nuclear science and technology since 1954, is the basis of science and technological capabilities for constructing and pursuing NPP soon. Indonesia becomes the leading country on nuclear technology in South East Asia especially its operating experiences of nuclear research reactors. The nuclear industry, which is based on non electric application has already pursued such as for agriculture, medicine and hospital utilizations, etc. Indonesia is preparing to build the first 2 NPPs which will be constructed within 2010-2015 and they will contribute 4% electric share to the total national energy mix by 2025. New and renewable energy resources can be well maintained not only based on energy resources approaches but also should be conducted by technological capabilities approaches. While preparing and fulfilling all international standard as a basic infrastructure for a nuclear power project, increasing public trust and confident in all regulations especially in providing well information on benefits and challenging on utilization of NPP should be well prepared and continuously improved. "Go nuclear" now is one of the issues not only in relation to the energy crisis, economical aspect and environmental challenges, but also a strategic position of Indonesian in Asia Pacific especially in ASEAN countries. If Indonesia does not "go nuclear" now, Indonesia will be surrounded by neighboring countries who wish to have a nuclear program soon such as Vietnam, Thailand, Malaysia and Singapore etc. for their own national energy security. In this situation, without any nuclear industry in Indonesia, some of Nuclear human resources will be invited and transferred to neighboring countries as an experts and will be difficult to bring them back to Indonesia. In short, synergy with all stakeholders, local government, public and local society, to make a statement "go nuclear" can be adopted as a part of solution for Indonesian energy program.

References

[1] West JM, Davis WK, The creation and beyond: Evolutions in US nuclear power development, Nuclear News, June 2001.
[2] http://www.icjt.org/an/tech/jesvet/jesvet.htm
[3] MPEL, HIMNI, METI, IEN, WIN, 5 NGOs, *PLTN Menjamin Ketahanan Penyediaan Listrik Nasional, "Naskah Pernyataan Sikap"* (2010) Jakarta (In Indonesian).
[4] *Book of presentations of Tokyo tech COE-INES-Indonesia International Symposium* (2005) Prospect of Nuclear Energy in Indonesia, Bandung, Indonesia
[5] Departemen Energi dan Sumberdaya Mineral, *Blue print pengelolaan energi nasional 2005-2025* (2005) Departemen Energi dan Sumberdaya Mineral (www.esdm.go.id) (In Indonesian).
[6] Ibrahim AH, *General Check-up Kelistrikan Nasional* (2008) (In Indonesia).
[7] Peraturan Presiden No 5 Tahun 2006, *Tentang Kebijakan Energi Nasional* (2006) (In Indonesian).
[8] www3.ntu.edu.sg/home/sulfikar/nuclear-revival.pdf
[9] Agenda Riset Nasional 2010-2014, *Kementrian Riset dan Teknologi* (2010) (In Indonesian).
[10] IAEA-TECDOC-151,l Basic infrastructure for a nuclear power project, and IAEA NuclearEnergy Series No. NG-T- 3.2