

THE ON-GOING PROGRESS OF INDONESIA'S EXPERIMENTAL POWER REACTOR 10 MW AND ITS NATIONAL RESEARCH ACTIVITIES

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ABSTRACT

THE ON-GOING PROGRESS OF INDONESIA'S EXPERIMENTAL POWER REACTOR 10 MW (RDE-10) AND NATIONAL RESEARCH ACTIVITIES. The RDE-10 program was firstly launched to the Agency for National Development Planning (BAPPENAS) in 2014. The RDE-10 program is expected to devote positive impacts to community prosperity, self-reliance and sovereignty of Indonesia. The RDE-10 availability will be able to accelerate advance nuclear technology development and hence Indonesia will turnout to be the nuclear champion in the ASEAN region. The application of RDE-10 performs an added value of local content and hence develops a model to fulfill the need of raw-material industry which is still imported from other countries. The success of development, operation, maintenance and utilization of RDE-10 will be able to enhance public acceptance on nuclear technology in Indonesia. This paper entitles background and design specification of RDE-10, challenging on budgeting and site licensing, national capacity building and its significant implementing research activities, concluding remarks, acknowledgement and references. Indeed, the paper can be assigned as a reference in planning, construction and operation of RDE-10 in Indonesia.

Keywords: RDE-10, Indonesia, current status, development.

ABSTRAK

STATUS TERKINI PEMBANGUNAN REAKTOR DAYA EKSPERIMENTAL INDONESIA (RDE-10) DAN KEGIATAN RISET TERKAIT NASIONAL. Program pembangunan RDE-10 sampai saat ini telah berjalan sejak awal 2014 ketika pertama kali Blue Print (Cetak Biru) RDE-10 disampaikan ke Bappenas. Program pembangunan dan pengoperasian RDE diharapkan akan memberikan dampak positif terhadap kesejahteraan masyarakat, kemandirian dan kedaulatan bangsa. Keberadaan RDE dapat mengakselerasi berkembangnya teknologi nuklir generasi maju di Indonesia sehingga menjadi unggul di kawasan regional. Aplikasi RDE dapat meningkatkan nilai tambah produk sumberdaya lokal, sehingga dapat dijadikan model dalam memenuhi kebutuhan industri bahan baku, yang selama ini bergantung pada impor. Keberhasilan nasional dalam pembangunan, pengoperasian dan perawatan serta pemanfaatan RDE dapat meningkatkan penerimaan publik terhadap teknologi nuklir. Makalah ini menyampaikan latarbelakang dan desain spesifikasi RDE, tantangan pendanaan dan perijinan, pengembangan SDM nasional dan kegiatan litbang utama terkait, kesimpulan, penghargaan dan acuan. Sangat diharapkan makalah ini dapat dijadikan pedoman dalam perencanaan, pembangunan dan pengoperasian RDE-10 di Indonesia.

Kata kunci: RDE-10, Indonesia, status terkini, pembangunan.

INTRODUCTION

The Act number 17 year 2007 on the Long Term of National Development Plan (RPJPN 2005-2025) and The Attachment of The Government decree Number 14 Year 2015 on The Master Plan of National Industry Development 2015-2035 (RIPIN 2015-2035) have authorized the application of nuclear energy considering very strict safety in 2015-2019, as well as the use of nuclear-energy-generated industry commencing 2020 [1,2]. In addition, in the Plenary Meeting of the National Energy Chamber (DEN) held in June 2016, the President of the Republic of Indonesia commanded the development of power research reactor and supporting laboratories in which Indonesian nuclear experts are able to express, interact, create and support all nuclear research activities in the country and all significant

results can be preserved to strengthen international collaboration and hence the world latest nuclear technology always be well informed.

Based on the Act number 10 Year 1997 as well as the Government Decree Number 2 Year 2014, BATAN (The National Nuclear Energy Agency) has the authority to implement nuclear research activities as well as to construct, operate and commission of non-commercial nuclear reactor in the country. In regards with that subject and as the World trends [3], BATAN decided to develop High Temperature Gas-cooled Reactor (HTGR) to be available in Indonesia. The HTGR technology has been selected since the HTGR not only has a very safe performance but also can be utilized for other purposes, such as, water desalination, hydrogen production, coal liquefaction, etc. [4]. The reactor not only consumes fuel flexibility [5], but also is proven technology, competitive price, and has a commercial prospect in the near future as some advanced countries (Germany, USA, PRC, Japan, RoK) have performed significant R&Ds on these kinds of HTGRs since 1980s [6-14]. The reactor can also be expanded to support small-medium electric power in the Eastern part of Indonesia.

The impression to develop HTGR, called as RDE-10 project, was originated from a talk between the Vice Minister of National Development Planning and Chairman of BATAN at the end of 2013. The idea was then conferred in the trilateral meeting between BAPPENAS, Ministry of Finance and BATAN. Due to appeal of BAPPENAS, the main related stakeholders of University of Indonesia/UI, Bandung Institute of Technology/ITB, Gadjah Mada University/UGM and The Agency for Assessment and Application of Technology/BPPT then supported the development of RDE-10 in Indonesia [15]. Indeed, there have been nine pre-project activities since 2014 including preparation of land use for RDE-10, RDE blue print, site license process, conceptual design and FEED (Front End Engineering Design), feasibility study, pre safety analysis report (PSAR), reactor main data, reactor information design, international collaboration, ten drafts for construction permit, project management and technology trainings held in domestic and foreign country and the establishment of project management organization [16].

Vision, Aims of RDE-10

The vision to build RDE-10 is to enhance Indonesia to be a nuclear champion in ASEAN region as well as nuclear technology provider to advance HTGR for electricity and cogeneration for industry in the future as seen in Figure 1. The final aim of RDE development is of the country strategic policy in energy sovereignty and the existence of the nation in the future. The RDE is utilized to condense the fossil-generated electricity, self-reliance on energy, and not only to enlarge local industry participation and to lead the regional and global economy, but also to strengthen politics and energy diplomacy. RDE will technically produce 2.9 MWe (Mega Watt electric) and only 0.4 MWe will be utilized for internal operation and the rest will be applied for BATAN internal electric supply as well as for community-need electricity around the RDE site. Moreover, the 1 MWe will be indeed equivalent to 1,000 house holds or 1,000 Watt each. Moreover, RDE is devoted for a demo plant from nuclear research reactor producing electricity. RDE can be a reference plant of small-power generating plant and is also very suitable to support small-medium-electricity-need regions. The RDE is projected to reinforce local industry participation and hence reducing the import dependence on other countries. The RDE is keen to intensify public acceptance on nuclear power plant (NPP) and is believed to advance national capacity building not only in nuclear research activities, but also in manufacturing and construction to support nuclear industry in Indonesia.

RDE Site has been selected in Puspipstek Serpong, Kota Tangerang Selatan and the site provided is around 8,674 ha. The site has been decided based on a temporary use permit from the Ministry of Research, Technology and Higher Education Number 1402/A/PL/2015, dated August 21, 2015, and the Ministry of Finance Number S-26/MK.6/2016, dated on 14 March 2016. The location of RDE is around 500 meters from the existing 30 MW RSG-GAS reactor in which BATAN has safely functioned it since 1987. It is noted that the national nuclear regulatory body (BAPETEN) has declared a site permit for RDE dated on January 23, 2017 and the permit is valid for 4.5 years.

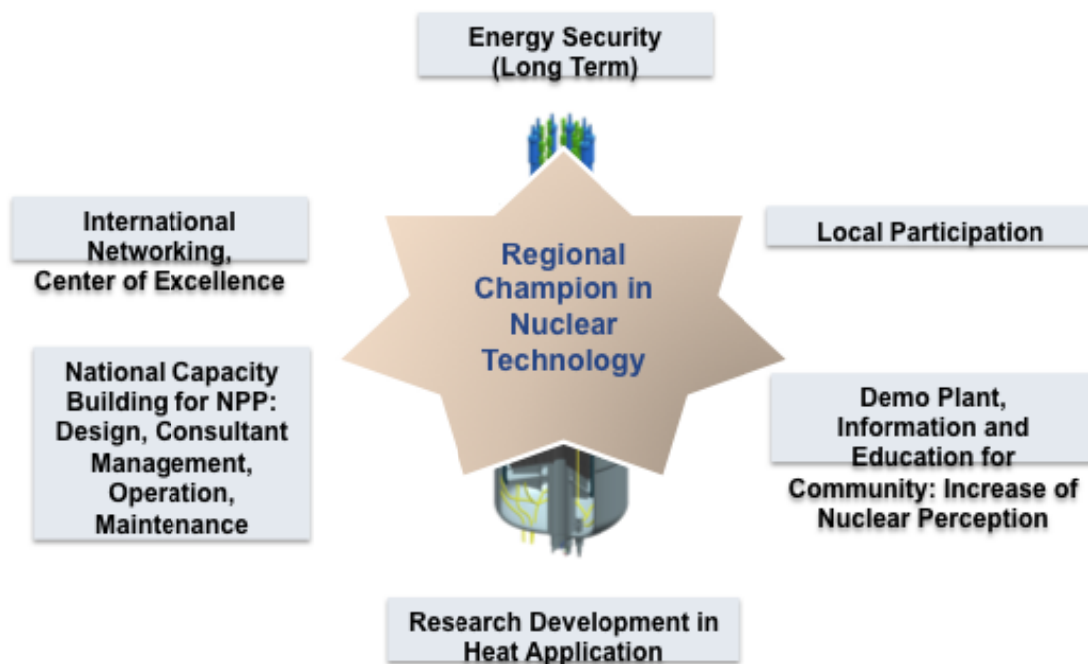


Figure 1. The advantages of RDE-10 project

The users for RDE are BAPETEN, BATAN, research agencies/ministries to proceed R&Ds on new and renewable energy, universities to educate qualified, young researchers, the related state-owned companies to support energy-mixed, local government to reinforce technological tourist object, local industry manufacturer, petrochemical and mineral companies, international institutions to do joint research in RDE, etc. By the existence of RDE, Indonesia will face a new era of advance nuclear technology Gen-IV and become a nuclear champion in ASEAN region and hence implementing welfare-self-reliance-sovereignty based community. This paper entitles background and design specification of RDE, challenging on budgeting and site licensing, national capacity building and its significant research activities, concluding remarks, acknowledgement and references.

CURRENT STATUS OF DEVELOPMENT FOR RDE-10

Design features of RDE-10

The Generation-IV consortium seeks to develop a new generation of nuclear energy systems for commercial deployment by 2020–2030 and one of the systems selected for development is a very high-temperature gas-cooled reactor (VHTR) [3]. The safety of a high gas temperature reactor (HTGR), one of the VHTR types, is very definite and the HTGR is becoming world trend to fulfill not only the need of electricity, but also to apply for other purposes, such as, hydrogen production, water desalination, coal liquefaction etc. The first success of HTGR was introduced in Germany when HTGR fuels were successfully invented in Harwell 1957. Through five decades of development, the German UO₂ coated particle and US LEU UCO coated particle represent the highly successful coated particle designs up to now [17]. The development of HTGR fuels has been of major concern of the world trend in the last two decades. However, referred to the success of HTGR operation, at the end of 2000, the Chinese 10 MW high temperature gas-cooled reactor (HTR-10) attained its first criticality on December 21, 2000 [13]. RDE, an HTGR type, and also one of the VHTR types as mentioned earlier, has been selected since RDE-10 is also taken into account the Multipurpose Power Reactor. In general, the design specification of RDE-10 is shown in Table 1.

Table 1. Design specification of RDE-10 [18].

Basic data		
Reactor power (thermal)	10	MW (Thermal)
Mean power density	2	2 MW/m ³

Core diameter	1.8	M
Mean core height	2.0	M
Primary system pressure	30	Bar
Flow direction	Downwards	
Primary coolant temperature (inlet/outlet)	250/700	°C
Fuel	Low-enriched uranium	(LEU)
Feed method	Multiple recycle	(MEDUL)

Equilibrium core nuclear data

No. of radial enrichment zones	1	
No. of fuel element recycles (avg.)	5	
Heavy metal charge	5	g/fuel element
No. of fuel elements in core	27,000	pcs.
Integral fuel element residence time	1,160	VLT
Fuel element dwell time	230	VLT
Enrichment	17	w/o
Target burn-up	80,000	MWd/MgU
Mean fuel element output	0.37	kW/fuel element

Fuel inventory

Heavy metal (excluding fission products)	138	Kg
fissionable materials	23.5	Kg
Maximum neutron fluency at side reflector (E greater than or equal to 0.1 MeV; after 32 full-load years)	6.8×10^{21}	cm^{-2}

1st Shutdown System (Reflector Rods) -> New: Rods outwardly going

Rods	10	Pieces
Absorber length	2,200	Mm
Absorber diameter	100	Mm
Maximum travel	2,600	Mm
Normal speed	1	cm/s
Absorber material	B ₄ C	

2nd Shutdown System

Shutdown units	7	Pieces
Small ball shutdown element diameter	5	mm
No. of small ball shutdown elements per unit	2.7×10^5	Pieces
Absorber material	B ₄ C in graphite matrix	(25% B ₄ C by volume)

RDE site licensing and budgeting

Referred to the applied law as mentioned in the beginning of this paper, for the construction of new commercial and non-commercial nuclear reactors, some permits must be fulfilled, such as, site and construction permits, commissioning, and operation licenses [19]. To date, BATAN has possessed a nuclear power site permit for RDE since January, 23, 2017. This must be appreciative since the site permit is the first history in the ASEAN region released by the national nuclear regulatory. Based on the law, RDE is categorized as a non-

commercial nuclear research-based power reactor, so that BATAN can propose the site permit to BAPETEN. BATAN had a lot of efforts to bear the site permit through firstly initiating a document of management system as well as that of site evaluation program to the regulatory body in September 2014. The former displays system management on planning, design, construction, commissioning, operation and decommissioning of RDE. The latter demonstrates all regular schedules, implementation and evaluation of site investigation activities dealing with earthquakes/seismology, volcanoes, geo-technic and foundation, meteorology, hydrology, human-base accident, and dispersion and populated distribution.

To deal with process of site licensing, firstly, BAPETEN has collaborated with The State University of Indonesia (UI) dealing with management system. Secondly, the Regulatory Body was in cooperation with Bandung Institute of Technology (ITB) covering all site aspects. As a licensee, BATAN also collaborated with the Agency for Meteorology, Geophysics and Earthquake (BMKG) and the Agency for Geology. Program of Site Evaluation and Management System of Site Evaluation was approved by BAPETEN on 25 February 2015. BATAN then proposed an application for Site Licensing for RDE to BAPETEN in October 2015. As standard operational procedure, the site licensing proposal documents were reviewed and all findings were then delivered to BATAN. BATAN completed a lot of efforts to revise all findings and BAPETEN fortunately held some trilateral meetings among BATAN, BAPETEN and its technical consultant. In three lateral meetings, all participants have ever visited site inspection especially for hydrology, seismic and foundation aspects. After all findings revised, BAPETEN finally released the site licensing for RDE on January 23, 2017. It was originally planned to have a trilateral formal meeting among BATAN, BAPETEN and IAEA (*International Atomic Energy Agency*) in September 2016. However, the three-party meeting was then employed in the last week of March 2017 and in the meeting, the Agency accomplished that BAPETEN has implemented all site licensing standard processes as properly as other countries do.

At the end of 2015, consortium of Indonesia-Germany completed conceptual design and FEED (front end engineering design), feasibility study, design information question (DIQ), main specification of reactor and pre safety analysis report (PSAR) of RDE. Come along with all documents carried out by the consortium, in 2016, BATAN completed Revision 0 of Document for Construction Licensing of RDE, Review Process and Quality Improvement of Site Licensing Documents delivered to BAPETEN, Preparation of Bidding Documents/TORs for Consultant of Planning and Company for EPC-RDE), Feasibility Document to support Bluebook RDE delivered to BAPPENAS. For the time being, BAPPENAS is still reviewing the Feasibility Study Document of RDE Revision 2 [16] to become a National Blue Book. The Blue Book is expected to be concurred by BAPPENAS in May 2017 and hence a green book consisting of the real agenda of RDE project will be released seven months later. The green book is considered to assure the civil construction of RDE to be commenced in 2018.

NATIONAL RESEARCH ACTIVITIES TO SUPPORT RDE-10 AND NATIONAL CAPACITY BUILDING

Referred to the Government Decree Number 79 Year 2014, the Indonesia Government supports and strengthens the development of energy industry and hence speeding up the energy supply and its application, national economy extension and labor worker absorption [20]. Based on the decree, it is estimated that the national need for electricity is 115 GWe by 2025 and to reduce the dependence on coal, the use of new and renewable energy (NRE) cannot be neglected. The previous mentioned decree also mandated that the application of NRE of 17% should be implemented. To become the use of NRE for electricity, as nuclear is one of NREs, the use of nuclear-based electricity has been adopted as mentioned in Ref. [21]. For dense population, such as, Java and Sumatera islands, the bigger nuclear power of 1,000 MWe is very proper. However, for the Eastern part of Indonesia which has smaller population, the smaller nuclear powers of 200-300 MWe will be suitable. The HTGR, RDE-base type having the power range of 150 MWe to 200 MWe, will be very appropriate in that area. To begin with and to support the mandate on the acceleration of NRE industry, nuclear-base research activities should be soon determined.

Local industry participation

During the construction of RDE-10, there will be a lot of knowledges dealing with project management organization and all aspects, such as, nuclear and safety, mechanical, electrical, process, instrumentation and control (I&C) and civil. In the first quarter of 1980s, Indonesia, specifically BATAN in Puspiptek area Serpong, had ever experiences on the construction of Multi Purpose Reactor, called RSG-GAS reactor, and its supporting laboratories, such as, centers of radioisotope, radiopharmaceutical, and nuclear research reactor fuel element production, and both are now belonged to the state-owned company Indonesia Nuclear Industry (INUKI). In addition, the others are also fuel element, nuclear safety and technology and radioactive waste treatment centers as well as nuclear facility engineering center and most of these facilities have safely operated since 1987. It is highlighted that all civil construction and non-nuclear-safety related devices supervised by the reactor vendor were executed by Indonesia engineering companies. From the latest assessment carried out, it is estimated that all RDE construction will be at least 40% supported by local engineering companies as seen in Table 2.

Table 2. Local participation for RDE construction [22].

No.	Cost component	%	Cost element					Total of cost element	Local participation (%)
			L (20%)	Com (18%)	ME (40%)	FD/ID (8%)	E/D/P (14%)		
1.	Plant concept, SAR, detail eng.	03.94	10	10	25	8	7	60	02.36
2.	BOP	17.87	20	15	30	8	12	85	15.21
3.	Buildings	12.88	20	15	35	8	14	92	11.85
4.	Electrical Systems	06.44	20	15	30	8	10	83	05.35
5.	I&C	09.67	10	9	20	8	7	54	05.22
6.	NSSS	48.84	0	0	0	0	0	0	0.0
	Component handling	0.36	20	18	40	8	14	100	0.36
7.	Total Cost	100.0							40.35

Note: L: Labor; Com: commodities; ME: major equip; FD/ID: filed/in direct; E/D/P: Eng/Des/Proc.

Due to the construction of RDE-10 and to maximize participation of the local companies in nuclear industry, a lot of integrated research activities should be begun and collectively implemented in ministries, agencies and universities. They are requested to propose such research activities and hence all research activities being able to be collectively carried out to achieve national goal on self-reliance of nuclear technology and industry. All collective research activities should be principally integrated by the Ministry of Research Technology and Higher Education.

Main stakeholder responsibilities

To begin with the national goals as stated in RIPIN 2015-2035 [2] and due to RDE-10 research activities, the Ministry also published The Master Plan for National Research 2015-2045 (RIRN 2015-2045). National Research activities for 2015-2019 are based on The long Term National Development Planning (RPJPN) 2005-2025, RPJMN 2015-2019, *Buku Putih Iptek* (white paper of research technology), The Agenda of National Research (ARN 2015-2045) [23], RIPIN 2015-2035, *Nawacita* and other relevant important documents. The related agencies, ministries and agencies have tasks as follows:

1. The Agency for National Development Planning/Ministry of National Development Plan (BAPPENAS) and Ministry of Finance (MoF): To make decision on mid and long term national planning especially in nuclear energy-based industries and to guarantee finance for their research activities which can be supported from national budget, joint venture as well as from G to G soft loans.

2. Ministry of Research Technology and Higher Education: To integrate all nuclear-base research activities in the country. For universities/institutions, researchers can be from University of Indonesia (UI), Bandung Institute of Technology (ITB), Gadjah Mada University (UGM) can be requested to take parts on nuclear research activities to develop and achieve nuclear industry in the country.
3. Ministry of Industry: To integrate all research activities on the engineering-based nuclear energy industry
4. Ministry of Energy and Mineral Resources: To ascertain national energy need in the future as well as to implement research activities on new and renewable energy following the Government Decree Number 79 Year 2014 on National Energy Policy 2014-2050 as well as the General Plan of National Energy till 2050.
5. Ministry of Cabinet Secretary and Ministry of Law and Human Rights: To institute all applicable laws to support research activities on new and renewable energy,
6. Ministry of Public Work and People Housing: To do research and development on nuclear-based civil construction.
7. BAPETEN: To set up all nuclear safety laws of nuclear-energy-based electricity for advance nuclear technology.
8. BATAN: To form and improve technical support organization (TSO) on present and advance nuclear technology.
9. BPPT: To establish a clearing house for all non-nuclear technology,
10. Agency for National Standard (BSN): To bring about all national standards to support peaceful uses of nuclear technology,
11. Universities: To implement nuclear-based research and to support the human resource development to do R&D in nuclear science and technology,
12. Ministry of State-owned company (Pertamina, PLN, Engineering Company): To establish research collaboration between state-owned companies and ministries/agencies to achieve nuclear industry,
13. Ministry of Foreign Affairs: To implement the lobbying on politic and nuclear energy policy in the ASEAN and global regions.
14. Ministry of Communication and Information: To establish public education and public information on nuclear energy.
15. LIPI: To prepare and establish research activities on social engineering and hence people living in the NPP-surrounding site can accept nuclear technology freely.

As mentioned earlier, the local content percentage of RDE-10 construction will involve as minimum as 40%. For local industry participation, Republic of Korea and Japan are now dealing with 90% of all NPPs (nuclear power plants) available in their countries and the rest of 10% is taken into account to balance the global economy [24]. For Indonesia, it is very reasonable to maximize the local nuclear industry participation of 70% by 2035. A lot of integrated industry-based research activities should be implemented as late as 2018. Indeed, the philosophy of what ministries/agencies/universities doing what activities should be clearly defined. The summary of research activities to develop and establish nuclear industry in the country is displayed in the following Table.

Table 3. Goals of research activities for nuclear industry 2015-2035

	Ministries or Agencies	Goals of Research activities	Duration	Big Goal 2035
1	National Planning and Finance	Decision on strategic planning of national industry development and on supporting its financing	2018-2035	
2	Ministry of Research Technology and Higher Education	Coordinating and budgeting of integrated research activities	2018-2025	
4	Energy and Mineral Resources	Establishment of national energy need in the future	2018-2025	
5	Ministry of Law and Human Rights	Establishment of applied law and rules to support integrated national research	Every year	

		activities		
6	Ministry of Public Work and People Housing	To implement research development on civil nuclear-based construction	2018-2035	
7	Ministry of Industry	To coordinate all applied researches on engineering-based nuclear energy industry		
8	Ministry of Cabinet Secretary	To support the establishment of government and president decree dealing with nuclear research activities	Every year	70% LOCAL-BASED NUCLEAR INDUSTRY
9	BAPETEN	Preparation and establishment of nuclear applicable law	2018-2025	
10	BATAN	Establishment of technical support organization on nuclear technology	2018-2025	
11	BPPT	Clearing house on non-nuclear technology	2018-2025	
12	Agency for National Standard	Preparation and establishment of national standard for nuclear industry	2018-2025	
13	Universities	Implementing nuclear-based research and supporting HRD	2018-2025	
14	State owned company (BUMN): Pertamina, PLN, Engineering Company	Establishment of collaboration for research activities on mechanical, electrical, instrumentation, balance of plant, etc.	2018-2025	
15	Foreign Affairs	Implementation of lobbying on politic and nuclear energy policy	2018-2025	
16	Communication and Information	Promotion and public education on nuclear energy	2018-2025	
17	LIPI	Research establishment on research of nuclear-based social engineering	2018-2025	

National research activities to support nuclear industry

To support national research activities for nuclear industry, the main topical researches should be focused on plant concept and detail engineering, buildings, electrical, instrumentation and control system (I&C) and nuclear steam supply system (NSSS). Every topical research will be explained in the following paragraphs.

Firstly, In general, the construction of RDE will begin with its conceptual design and as mentioned earlier, the conceptual design of RDE was completed at the end of 2015. The RDE conceptual design was carried out by consortium of local engineering company, Rekaya Engineering, for non-nuclear islands and German company called NUKEM GmbH for nuclear islands. Furthermore, it should be highlighted that 40% of the design was successfully done by local company, and the rest was carried out by the foreign company as previously explained. To continue the activities of RDE, in 2016, BATAN developed project management organization (PMO) to mediate such activities in which BATAN and vendor candidates are involved. In addition to PMO, BATAN also established mainly some teams, such as, budgeting-feasibility team, site and licensing team, safety analysis report (SAR) team, and design team. While, the feasibility team is persistent to collaborate with BAPPENAS team to speed up the RDE-10 project to be one of the Program Blue Books for 2017, the site and licensing team was successfully to bear the RDE-10 site licensing in

January 2017. The SAR team also developed pre safety analysis report (PSAR) of RDE and the report was already reviewed by the Agency Representatives. The reviewer considered the RDE report classified as the PSAR world class.

Secondly, BATAN has recently established the RDE design team to improve the RDE conceptual design and hence becoming the RDE basic engineering design package (BEDP). By using the BEDP, the cost of the RDE EPC (engineering, procurement and construction) can be estimated accurately. Furthermore, the Ministry of Industry has recently been interested in collaborating with BATAN to implement the project RDE into the phase of EPC. Some local engineering companies are also very impressive to construct the RDE at due time and they even estimate the local content for RDE around 50%, 10% more than previous estimate. The result of BEDP should however be reviewed by foreign nuclear engineering company or the reviewer from the International Atomic Energy Agency (IAEA) due to IAEA code of conduct for nuclear safety.

Thirdly, as previously mentioned, RDE basically consists of balance of plant, buildings, electrical systems, Instrumentation and control (I&C) and component handling and those are classified as non-nuclear islands. However, NSSS is nuclear island which is mostly supported by foreign nuclear companies. Moreover, balance of plant is one of the main parts in RDE and the BOP mainly contains chillers, diesel gensets, gas compressors, generators etc. [25]. BATAN is possibly to collaborate with some local engineering companies especially for dealing with BOP implementation for EPC of RDE. From Table 3, it is clear that, 85% of BOP work will be able to be conducted by the local engineering companies. Those have been proven when BATAN implemented the RSG-GAS construction and its supporting laboratories in Kawasan Puspiptek Serpong from 1980s to 1990s. From BATAN investigation, steam turbine and generator, power of more than 1000 MW thermal, which are mainly those of BOPs have even been fabricated in Cilegon industry area. It is then assured that there should not be more research activities to be done on BOP.

Fourthly, for the buildings as previously mentioned in Table 3, 92% of all works can be supported by local engineering companies and the rest is only related to the installation of NSSS, such as, pressure vessel, reactor core, primary cooling system etc, and the work deals with mainly on welding of the NSSS installation classified as nuclear standard. Moreover, from Table 3, it is shown that electrical system of RDE can be 85% supported by local companies since this is a group of non-safety related electrical system. However, the electrical system related to nuclear controlling system is classified as nuclear island system and the research collaboration with foreign nuclear institution should be developed.

Finally, instrumentation and control (I&C) of RDE covers display, monitoring and control and the first and second parts can be surely handled by the local engineering companies, since they have been long involved in big power of coal plant in Indonesia. Furthermore, the control system of RDE, or NPP in general, is classified as nuclear-safety related system, so that the collaboration between local and foreign-nuclear companies can not be neglected. Lastly, Nuclear Steam Supply System (NSSS) is 100% nuclear islands, so that the cooperation on research activities with important foreign institutions should be soon defined and implemented.

CONCLUSIONS

The RDE development has become a progressive national program since the program has been fully supported not only by the related Acts, but also the mandate of President of the Republic of Indonesia in which nuclear Indonesia experts are able to express, interact, create and support all nuclear research activities in the country and all significant results can be preserved to strengthen international collaboration and hence the world latest nuclear technology always be well informed.

The RDE will be a very good experience, especially for BATAN and related stakeholders, to gain national capabilities in nuclear fields. The smaller power of RDE developed in the eastern part of Indonesia can optimize the use of natural resources, such as, thorium, zirconium and others. Since the RDE project will be partly financed by national budget, the existence of the project will open opportunities to local industries to participate in the RDE construction, especially in civil construction as well as in non-safety related devices to achieve the goal of 70% local-based nuclear industry in 2035, all integrated research activities focusing on nuclear industry should be soon defined and implemented by the responsible ministries/agencies/universities. For nuclear research activities concentrated on

nuclear safety-related systems, the collaboration with foreign institutions and/or Agencies should be soon carried out.

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