The Challenges of Implementing the Indonesian Experimental Power Reactor (RDE) Program

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Abstract. This paper shows the effort to implement the RDE and its challenges from 2013 to 2018. RDE was a program to introduce nuclear power plants by building non-commercial power reactors. The RDE program was also used to prove that Indonesian engineers can design a reactor that will later supply electricity and steam for industry. The technology used is a high-temperature gas-cooled reactor. This RDE program is a very strategic intermediate target for energy security and national sovereignty. The development of RDE-based nuclear power plants, in the long run, is expected to have implications for reducing reliance on fossil fuels, more self-sufficiency in energy supply increases national industrial capacity and competitiveness in the global economic order, as well as enhance energy and political diplomacy. Also, RDE can be a reference installation for PeLUIt (Power and Steam Generators for Industry) power plants for small and medium enterprises to meet the demand for electricity and industrial heat in an area's needs. However, many challenges occurred to implement this program; among them were cost estimation and cost-benefit analysis. Although the program has not been realized, mainly for financial reasons, many positive things have been obtained from these activities.

1. Introduction

The idea of developing an experimental power reactor (RDE) was initiated through discussion between National Development Planning Agency (BAPPENAS) and BATAN in June 2013. Then followed up with a trilateral meeting between BATAN, BAPPENAS, and the Ministry of Finance, and has received support from related stakeholders (some universities and technology agencies). Although most Indonesians support the development of nuclear power plants based on a survey conducted [1], it is not easy to get a political decision to implement the nuclear power plant program so that RDE can be a breakthrough to avoid political complications in Indonesia. The Indonesian Government formally stated the RDE in the midterm national development planning 2015-2019 [2]. Nine RDE Pre-Project activities that have been carried out since 2014 to 2018 are (1) land allocation preparation and master plan preparation (coordination with Ministry of Research, Technology and Higher Education), (2) preparation of RDE Blueprint, (3) site permit process, (4) preparation conceptual design documents and Front End Engineering Design, Feasibility Studies, Safety Analysis Report, Reactor Main Data (DUR), and List of Reactor Design Information (DID), (5) International Cooperation (IAEA, Rosatom, INET / Tsinghua University, CNEC, JAEA), (6) HTGR- related workshops, (7) ten draft documents related to construction permits (DUR, DID, RDE Aging Documents, Radiation Protection,
and Accident Management), (8) training related to Project Management, technology, and safety both at home and abroad, and (9) the establishment of the Project Management Organization (PMO) Team.

This paper shows the effort to implement the RDE and its challenges from 2013 to 2018. Although the program has not been realized, mainly for financial reasons, many positive things have been obtained from these activities.

2. Purpose and Benefits
The purpose of developing RDE is to bring Indonesia to become a technology owner related to electrical energy and heat for the national industry in the long term. RDE development is a very strategic intermediate target for resilience energy, national sovereignty, and the existence of the Indonesian state in the future. Development RDE-based nuclear power plants are expected to have implications in the future for reducing dependence on fossil fuels [3], are more self-reliable in energy supply, increase industrial capabilities nationwide. The Government hopes that this program will also increase Indonesia’s competitiveness in the regional and global economic order [4]. Besides, RDE can be a reference plant for small and medium power reactors (50 s/d 600 MWe per unit) to meet electricity and industrial heat demand. The RDE may be compatible with the geographical condition of Indonesia as an archipelago that some areas require small/medium electricity power or those with small power grid capacity [6]. In line with that, the program of RDE may increase the capacity of the national nuclear industry in the field of manufacturing and construction capabilities, reducing dependence on the state other, as well as having a positive impact on increasing public acceptance of Nuclear Power Plant.

Besides that, some of the benefits related to RDE development for Indonesia are:

a. Improve energy security in the long term.
b. Mastery of development project management related to nuclear power plants, which will bring Indonesia, is among the countries for the design of the 4th generation.
c. Increasing the capacity of Indonesian human resources in mastering aspects of nuclear safety and make documents related to nuclear power plant licensing (especially site permits, construction permits, commissioning permits, and operating permits).
d. Increase national human resources (HR) capacity to design, construct, operate, and maintain nuclear power plants.
e. Improved R&D for heat/cogeneration applications.
f. Increase the capacity of local industries to support the nuclear industry.
g. Increase international networks.

The basic idea is that if the RDE project is successful, it will trigger larger commercial HTGR with the power of 50 to 600 MWe in various parts of Indonesia as needed. Thus, Indonesia will become a leading country in the ASEAN region and is expected to become a provider of HTGR type nuclear power plants domestically and in the region.

3. Location of RDE and Site Permits
The RDE site was selected in the Serpong Puspiptek Area. This selection streamlines the licensing process related to the site, which may take many years. The location of RDE is not more than 500 meters from RSG GAS 30 MW, which BATAN has managed for nearly 30 years. The land provided for RDE is 8,674 ha. The current status is already obtained a borrow-to-use permit from the Ministry of Research, Technology and Higher Education and the Ministry of Finance. The process of obtaining an RDE site permit has been carried out since 2014, covering seven aspects as required in the regulation on licensing for nuclear installations and utilization of nuclear materials. Namely the seismic aspect, utilities, geotechnical and foundation, meteorology, hydrology, dispersion and distribution population, and human-induced events. The Indonesian national regulatory agency (BAPETEN) approved implementing the RDE site evaluation on February 25, 2015. After that, activities of the site evaluation were carried out until 2016. Finally, the status of the RDE location has
met safety terms and criteria and has obtained a site permit from BAPETEN on January 23, 2017. This is the first experience for Indonesia to issue a location permit for a nuclear power plant. It is also unique because the RDE reactor design process was still ongoing, but the location has been approved.

Figure 1. The location of the RDE site at Puspiptek Serpong

4. Scope of Work Plan and Activity Components
The Project activities have a scope according to the RDE project stages with activity components as follows:

1. RDE Project Initiation Stage
   The scope of pre-project activities includes preparing blueprint, user requirements documents (URD), technology selection, feasibility study (FS), conceptual design, and site permit process.

2. The RDE Project Planning Stage
   The activities in this stage include principal permits, site permits, construction permits, commissioning permits, operating permits, and other permits.

3. RDE Project Implementation Phase
   Components of activities within this scope include basic engineering design and detail design, procurement, construction, process installation, and commissioning. Each stage of implementation is also related to the preparation, monitoring, and evaluation of human resources.

4. RDE Project Completion Stage
   This stage is the final stage of the project RDE development, where all the criteria of the RDE project (contract) have been fulfilled.

Unfortunately, the above plan has only been implemented in the first phase. At that time, the calculation of financing required a very long discussion. As a result, the Government considered this program expensive and ordered a review of the RDE development costs.

5. Challenges on The RDE, Cost estimation, and Funding
Costs in the development of RDE are classified into three types: investment costs, operational costs and maintenance costs, and nuclear fuel costs.

1. Investment or Capital Costs.
   Initially, Funding for the RDE program wanted to use the Government's budget. However, since nuclear facilities' construction is expensive, the Government considers loans from foreign financial institutions [7].

2. Operation and Maintenance Costs.
   Operation and maintenance costs consist of salaries for employees, spare parts, costs electricity, water and telecommunications consumables, and cleaning costs.
3. Nuclear Fuel Costs.  
Nuclear fuel costs include purchasing nuclear materials, fabrication, and transport to reactor and storage after use.

One of the RDE Project Initiation Stage results is the estimation cost of building RDE. The estimate is around 300 million US dollars, or equivalent to 4.3 trillion rupiahs. The Government considers these costs too expensive. This led BATAN to switch from a turn-key program to designing its RDE. This change also had a positive impact, namely that BATAN could estimate the cost of RDE development in more detail and at a lower cost. BATAN collaborated with several state-owned enterprises with experience designing and building non-nuclear power plants to calculate the cost of non-nuclear islands. BATAN has received support from the International Atomic Energy Agency (IAEA) and several partner countries for the nuclear island part. The costs for the RDE are as follows:

| No. | Component               | Unit          | Total  |
|-----|-------------------------|---------------|--------|
| 1.  | Investment              | Billion rupiah| 2.200  |
| 2.  | Operation and Maintenance| Billion rupiah/year | 142.57 |
| 3.  | Nuclear Fuel            | Billion rupiah/year | 36.4   |

**Detailed Funding Plan**

The detailed funding plan for the RDE development project is based on the needs budget, such as basic and detailed design activities, engineering, procurement and construction (EPC), and supporting activities for implementing the RDE project. Supporting activities include the preparation of human resources, licensing, and project management/management.

Based on calculating the cost per RDE component by the BATAN Team, RDE development needs are 164,805 million USD.

**Annual RDE Development Financing Pembangunan**

The estimated cost breakdown per year is based on activity and cost optimization, and HR costs are based on the S curve. The first year starts with preparing basic designs to detailed design and site preparation activities with a cost of about 12% of the total funding or 17,777 million USD. In the second year, it continued with site preparation and started the equipment procurement with 29,629 million USD (28% of the total Funding). Finally, the third year requires 41,480 million USD for construction and procurement equipment.

**6. Cost and Benefit Analysis**

One of the biggest challenges in assessing the feasibility of investment in constructing nuclear research facilities is assessing or estimating what benefits will be obtained by the Government in the future [8]. Given the estimated high cost of RDE development, the Government always asked about the benefits for the public. Of course, the most significant benefits provided by R&D facilities such as RDE are intangible or difficult to measure financially and do not directly affect the national economy. The benefits of developing an RDE, both tangible and intangible, are described below.

**Tangible benefits:**

1. Electricity production

   RDE capacity is designed for 10 MWh, which can produce electricity with a capacity of 2.9 MWe. The estimated use of RDE electricity for internal purposes is only 0.4 MWe, while the majority is 2.5 MWe for public purposes. With an annual operation of 6570 hours, at a capacity factor of 75%, RDE can produce 16,425 MWh per year. Considering the price of electricity by PLN, which is equal to Rp1,139 / kWh, BATAN per year can save as much as Rp.18.7 billion.
2. Nuclear Power Plant Design
   By referring to the RDE design, developing a larger nuclear power plant is possible in the future. The estimated cost for the RDE scale-up from research to final design is likely to be around USD 1.014 million. This profit belongs to the Government of Indonesia.

3. Human resource development
   The existence of the RDE program will increase the capability of human resources not only for BATAN but also for other stakeholders (universities, research institutions, state-owned enterprises, BAPETEN, state electricity companies, and others).

4. Patents
   The RDE program will enhance research on instrumentation and control, materials science, and new technological discoveries. Many patents can arise from these studies.

Intangible benefits:
Since intangible benefits are difficult to measure in terms of economic value, so some estimation has been made, i.e.:

1. Increasing Public Acceptance [9].
   With the RDE, the community will be able to accept the presence of the larger NPP. In addition, because of the RDE, promoting nuclear power plants is more comfortable and more effective in explaining safety and security factors because there is an example of a small power reactor operation.

2. Increased self-confidence.
   For a long time, Indonesia has three research reactors located in Bandung, Yogyakarta, and Serpong. However, it still does not have NPP. One of the causes is self-doubt in Indonesia to build and operate nuclear power plants. With the construction of RDE, it is expected to increase self-confidence, especially in decision-makers.

3. Become a referral center.
   Not many countries have developed the HTGR (High Gas Reactor Temperature) [10]. With the construction of RDE, Indonesia will become a reference center, especially for the regional area.

4. Maintain competence.
   Many nuclear human resources in Indonesia are on the verge of retirement, while the younger generation has minimal experience developing and operating nuclear reactors. Therefore, RDE development is significant in maintaining human resource capabilities.

7. Operation and Maintenance Plan
   In the planning, RDE will operate at full power of 10 MWth, or equivalent electricity production. 2.9 MW. It is planned that, in addition to various experimental activities, RDE's electricity production is used to meet the electricity needs of BATAN's laboratory facilities and possibly for the surrounding community. The experiments, including, among others, study the physical parameters of the HTGR reactor, safety experiments, thorium fuel experiments, and heat/cogeneration applications. It is expected that the RDE will operate in five modes: start-up, mains power operation, shutdown, test demonstration, and maintenance. This operating mode share is 75% for mains power operation and 25% for start-up, shutdown, demonstration or experimentation, and maintenance programs. Some of the experimental and demonstration plans that will be carried out in RDE are zero power experiment, full-power operation, demonstration of RDE's inherent safety, and heat application system (cogeneration experiments). Safety experiments include multiple crash demonstrations (including system outage/SBO accidents) to prove RDE's resistance to accidents such as the Fukushima incident. The scheme of safety experiments is similar to the activities on the HTTR (Japan) and HTR-10 (China) reactors. In addition, it is planned that there will be unique experiments that are not similar to the two reactors from Japan and China. Namely, trials of electricity generation systems that can later be used to design reactors with greater power on a commercial scale. The data obtained from the experimental results will be validated with the Calculation Code created and developed by the
BATAN team for understanding the process in depth. This validated data will be used to develop future nuclear power plant designs for the needs of Indonesia and other countries. The RDE maintenance program that will be carried out includes maintenance for preventive action and corrective action. Maintenance activities will be carried out regularly so that critical components continue to operate in good condition and support the safe, secure, and reliable operation of the RDE.

![Figure 2. Roadmap of RDE](image)

8. Conclusion
RDE will bring Indonesia to become a technology provider related to the provision of electrical and heat to support the needs of the national industry and be the leading country in the region. This RDE program is a very strategic intermediate target for energy security and national sovereignty. The development of RDE-based nuclear power plants, in the long run, is expected to have implications for reducing reliance on fossil fuels, more self-sufficiency in energy supply increases national industrial capacity and competitiveness in the global economic order, as well as enhance energy and political diplomacy. In addition, RDE can be a basis for PeLUIt (Power and Steam Generators for Industry) power plants for small and medium-sized businesses to meet industrial electricity and heat needs in an area. With the development of RDE, Indonesia will enter a new era of Generation IV power reactor technology that can bring Indonesia ahead in nuclear technology.

Although the program has not been realized, mainly for financial reasons, many positive things have been obtained from these activities. For example, from the RDE activities for four years, the mapping of stakeholders to build nuclear power plants has become more apparent. Likewise, the collaboration between research institutions, universities, and State-Owned Enterprises will be a vital asset in the future in building nuclear power plants. The special one is, even nuclear energy regulatory agencies can grant RDE site permits. Therefore, it is hoped that the Indonesian Government will reconsider the RDE program in the future.

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