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# PENILAIAN PRESTASI R&D TEKNOLOGI NUKLEAR: KAJIAN KES AGENSI NUKLEAR MALAYSIA

***Fairuz Suzana Mohd Chachuli, Mohd Azmi Sidid Omar, Azlinda Binti Aziz, Abdul Quddoos Abu Bakar and Faridah Mohd Idris***

Planning & International Relations Division,
Malaysian Nuclear Agency, 43000 Kajang, Selangor
Corresponding author: fairuz@nm.gov.my

***ABSTRACT***

*Nuclear technology has started in Malaysia since the establishment of the Malaysian Nuclear Agency (Nuclear Malaysia) in 1972. The agency was established to promote the peaceful application of nuclear science and technology for national development. Nuklear Malaysia also plays important role in providing research, development, commercialisation, and innovation (RDCI) in line with national interests, including industry, medicine and healthcare, food and agriculture, natural resources, energy, and nuclear safety and security. This paper aims to examine the performance and the growth of nuclear technology R&D in Nuklear Malaysia from 2011-2021 using the data envelopment analysis (DEA) and Malmquist index (MI) analysis. The study uses two inputs, namely RDC & Development budget (RM Million) and Operating budget (RM Million), and three outputs, namely revenue (RM Million), no. of R&D products and no. of publications. The result shows that the performance of nuclear technology R&D in Nuklear Malaysia is 96.70 per cent from 2011-2021. The study shows that nuclear R&D growth decreased by 8.3 per cent for the entire study period. The technological changes decreased at 8.3 per cent, while the efficiency changes remain. The study also found that nuclear technology R&D growth index in Nuklear Malaysia is mainly affected by technological changes due to policy changes compare to the resources provided since efficiency changes remain. The findings of the study help management and officials of Nuklear Malaysia to realign the institution's direction to ensure the nuclear technology RDCI contribute to the socio-economic development of the country.*

**Keywords**: *efficiency, growth, nuclear technology, performance, R&D*

## INTRODUCTION

Agensi Nuklear Malaysia (Nuklear Malaysia) marks its 50th years of anniversary in the year 2022 and highlights its important role as a premier research and development (R&D) organisation in nuclear science and technology in the country. Nuklear Malaysia also continues to play an active role and contributes to the implementation and realisation of national science and technology (S&T) policies to ensure it remains a relevant public research institute for the country (Nuklear Malaysia, 2022). After the 50th year of establishment, Nuklear Malaysia is mature and capable to face challenges and manage changes efficiently. Nuklear Malaysia has an emphasis on building the human capital potential and ensuring that all activities fit the mainstream S&T and national interest.

In realising the potential of S&T as an agent for new economic development for the nation, particularly in facing the global competitive market, Nuklear Malaysia has focused its R&D activities on six priority areas, namely advanced material, advanced manufacturing, biotechnology, ICT, advanced alternative energy, and nanotechnology (Nuklear Malaysia, 2013). With its multidisciplinary features, nuclear technology could offer a technical solution to arising technical problems. The R&D projects are market-driven to produce beneficial products to generate economic returns through downstream activities. Efforts have been made to ensure that research products can be commercialised through technology transfer and licensing. Continuous research efforts and knowledge expansion in nuclear science and technology are necessary to further technological innovation, which in turn brings about new benefits for country.

After the 50$^{th}$ year of establishment, it is a crucial time to evaluate the performance of nuclear technology R&D activities in Nuklear Malaysia which are mainly funded by the Government. Most research organizations, including Nuklear Malaysia are faced with increasing demands on their existing resources and there is a constant need to improve resource allocation and utilization. As the R&D process utilizes scarce resources, it becomes crucial to assess its efficiency. The assessment of R&D efficiency has the dual advantage of identifying the better performers for benchmarking and it also throws light on ways to improve efficiency by highlighting areas of weakness. The efficiency of the R&D process can be the ratio of the R&D outputs and inputs. The major inputs to the R&D process are expenditure on R&D and human resources. The outputs are patents and publications since both patents and publications are used extensively in measuring R&D efficiency and innovation.

This paper measures the relative efficiency of the nuclear technology R&D activities and the R&D growth of nuclear science and technology in Nuklear Malaysia from 2011-2021 using Data Envelopment Analysis (DEA) and Malmquist Index (MI) analysis. In this study, Nuklear Malaysia is selected as a case study since its role as a leading R&D organization in the field of nuclear science and technology in Malaysia. This paper would significantly contribute to future strategic decision-making on the success of R&D of nuclear science and technology activities in Nuklear Malaysia. The rest of the paper is organized as follows. The second section presents a review of the existing literature on R&D performance and growth. The third section describes the methodology followed in the current work. The results and discussions are presented in the fourth section. Section five summarizes the study and provides a conclusion.

**Literature review**

Some researchers have conducted studies on evaluating R&D performance to see institutional efficiency. An effective R&D operation is a major source of competitive advantage in today's rapidly globalizing economy. Thus, the evaluation of R&D performance has been the important problem for both academic interest and practical needs (I.J. Asmara et al., 2019). It is difficult to measure the R&D efficiency due to the complicated characteristics of these activities and DEA method is a widely used as a nonparametric approach to measure the R&D efficiency (O. Belgin, 2019). R&D efficiency attracts the attention of the researchers, and many papers can be encountered on the R&D efficiency of firms, institutions, academic research, countries, or regions.

Zhang et al. (2003) investigated the impact of ownership on the R&D efficiency of Chinese firms using the stochastic frontier estimation. They found that foreign firms have higher R&D and productive efficiency than domestic collective-owned enterprises and joint stock companies. The higher R&D efficiency of foreign firms appears to be due to a higher R&D intensity, which in turn leads to higher productivity. Lu (2009) investigated the R&D efficiency and marketability of Taiwan's IC-design firms using DEA. They found that it is not desirable that firms often ignore marketability in the R&D process. Chuang et al. (2011) measured the R&D efficiency of the Taiwanese semiconductor industry's new product development. They found that 58% of the IC semiconductor industry is efficient in new product development.

Bae and Chang (2012) analysed the impact of open and closed innovation on the performance of Korean firms. They found that both efficiency and effectiveness were statistically higher among open innovation firms than among their closed counterparts. It may thus be concluded that the acquisition of outside technology or knowledge has a positive impact on firm performance. Hung and Shiu (2014) evaluated the R&D efficiency of projects using three-stage DEA and Tobit regressions. They found that technology type and accumulative experience enabled R&D projects to be advantageously implemented in the human resource department, whereas group diversity was disadvantageous and created superfluous repetition in human resources. Chun et al. (2015) examined the efficiency of R&D processes of Korean manufacturing firms using two-stage DEA. They found that R&D efficiency is different by firm size and industry type. Jang (2016) measured the cumulative change in R&D efficiency of globally leading R&D companies in the technology industry using the DEA and Malmquist Index. Results indicated that the overall R&D efficiency of these globally leading R&D companies declined slightly during the period 2007–2013.

Khoshnevis and Teirlinck (2017) analysed the efficiency of R&D active firms using DEA models. They found that firms in specialized supplier industries tend to outperform, while firms in science-based industries are found to underperform. Qin and Du (2018) measured the R&D performance of universities in China's provinces using a network data envelopment analysis. They found that universities' R&D activities are considered efficient and effective only in a small number of provinces, while in most provinces, these activities can generally be considered less efficient and effective. Xiong et al. (2018) evaluated the R&D efficiency of Chinese research institutes using DEA. They found that the institutes experienced significant improvements in system efficiency, mainly due to the improvements in transfer efficiency. Fairuz et al. (2021) explored the performance of R&D activities in five renewable energy resources in Malaysia from 2012 to 2017 using DEA. They found that mini hydro is the most efficient renewable energy source in Malaysia, whereas wind is the most inefficient one from the perspective of R&D activities.

The current study uses two variables, namely RDC & Development budget (RM Million) and operating budget (RM Million) as input for R&D activities, whilst revenue (RM Million), number of R&D products and number of publications are identified as an output for R&D activities. The DEA model and the Malmquist productivity index analysis are used in this study to assess the R&D performance of nuclear technology in Nuklear Malaysia, as well as to evaluate the impact of the policy interventions, toward nuclear technology R&D in Nuklear Malaysia from 2011 to 2021 using these variables. The policy interventions related to nuclear technology R&D activities considered in this study are Malaysian Nuclear Agency Strategic Plan 2012-2020: Strategy and Action Plan, Dasar Sains, Teknologi dan Inovasi Negara (DSTIN) 2013 – 2020, 10$^{th}$ Malaysia Plan 2010-2015 (10$^{th}$ MP) and 11$^{th}$ Malaysia Plan 2016-2020 (11$^{th}$ MP).

## METHODOLOGY

### *DEA*

DEA is a widely used tool by academics and practitioners to assess the performance of firms. DEA is a comparison approach based on linear mathematical programming, in which units use multiple inputs to produce multiple outputs, resulting in a single measure of overall performance (F.S. Mohd Chachuli et al., 2020). Every DMU in DEA compares their efficiency to its peers by considering a variety of input and output criteria (H. Zhou et al., 2018). The DEA method is based on the mathematical technique to make the most efficient use of resources to meet a decision-making objective. According to Charnes, Cooper, and Rhodes (1978), the weighted total of output to the weighted sum of input for each DMU evaluation cannot exceed 1 (A. Charnes et al., 1978). The Charnes–Cooper– Rhodes (CCR) model and the Banker–Charnes–Cooper (BCC) model are two types of DEA models often used to estimate the degree of inefficiency in the input-output ratio, particularly to prioritise the ranking of each DMU. The BCC model's capacity to comprehend varied returns to scale (VRS) distinguishes it from the CCR model (R.D. Banker et al., 1984). Efficiency is measured on a scale of 0 to 1, where a value of 1 indicates the unit is relatively efficient, and a value less than 1 indicates the unit is inefficient. The efficiency score of a unit will vary according to the factors and DMUs included in the analysis.

For static analysis, this study employs the BCC-DEA model with the VRS assumption. The MI analysis is utilised for dynamic analysis to evaluate the impact of strategic papers on nuclear technology R&D activities in Nuklear Malaysia. The CCR-DEA output-oriented model is presented in Eq. (1) (R.D. Banker et al., 1984).

$Min\ \Phi$

Subject to

$$\sum_{j=1}^{n} z_i x_{ij} + s^-_j = x_0, (i = 1, \ldots, m)$$

$$\sum_{j=1}^{n} z_j y_{rj} - s^+_j = \theta_0 y_0, (r = 1, \ldots, s)$$

$$z_0 \geq 0, j = 1, \ldots, n$$

For VRS, add $\sum_{j=1}^{n} z_j = 1$, Eq...(1)

where $n$ is the number of DMUs. $m$ is the input and $s$ is the output for each DMU$_j$ ($j$ = 1,2, …, $n$). $x_{ij}$ (i = 1,2, …,$n$) is the $i$th input of DMU$_j$, and $y_{rj}$ is the $r$th output of DMU$_j$. Slack variables, $s^-_i$ and $s^+_j$, measure the excess of inputs and outputs. The efficiency value is denoted by $\theta_0$, which is in the range of (0,1].

***Malmquist productivity index***

The Malmquist productivity index analysis is employed in this study to assess productivity changes in nuclear technology R&D activity (N.K. Avkiran, 2006; C. Woo, 2015). The index is usually applied to the measurement of productivity change over time and can be multiplicatively decomposed into an efficiency change index and a technological change index. The Malmquist productivity index was generalised by Färe and Grosskopf based on the geometric mean of two indices (R Fare, 1994). This index examines the change in productivity between periods $t$ and $t$+1 (D.W. Caves, 1982). In addition, this index compares the ratios of two distance functions to determine their productivity (A.N. Menegaki, 2013).

Eq. (2) expresses the Malmquist productivity change which has two parts: technical efficiency change (EFFCH) and technological change (TECHCH), as follows [33]:

$$M_t^{t+1} = \left[\frac{D_0^t(x_0^{t+1}, y_0^{t=1})}{D_0^t(x_0^t, y_0^t)} \frac{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^t, y_0^t)}\right]^{1/2}, \quad \text{Eq...(2)}$$

$$EFFCH = \frac{D_0^t(x_0^{t+1}, y_0^{t+1})}{D_0^t(x_0^t, y_0^t)}, \quad \text{Eq...(3)}$$

$$TECHCH = \left[\frac{D_0^t(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \frac{D_0^t(x_0^t, y_0^t)}{D_0^{t+1}(x_0^t, y_0^t)}\right]^{1/2}, \quad \text{Eq...(4)}$$

where $M_t^{t+1}$ is the index between periods $t$ and $t$+1; $D_0^t(x_0^t, y_0^t)$ and $D_0^{t+1}(x_0^t, y_0^t)$ are the distance functions between $t$ and $t$+1 for inputs and outputs, respectively.

In Eq. (2), efficiency increases if $M_t^{t+1}$>1, remains constant if $M_t^{t+1}$=1 and decreases if $M_t^{t+1}$<1.

In Eq. (3), the EC component calculates the catch-up impact of whether a specific DMU is closer or further away from the production frontier in periods $t$ and $t$+1. The frontier shift effect or TC quantifies the technological progress or regress of DMUs between $t$ and $t+1$.

The Malmquist productivity index is a dynamic analysis tool designed to compensate for the inadequacies of DEA. DEA can only examine a static scenario during a specified period. Without assuming a preset production index, the Malmquist productivity index assesses the ratio of input to output, allowing for a dynamic assessment of efficiency changes. The Malmquist productivity index is computed by multiplying EFFCH and TECHCH. EFFCH represents the difference in the object of study's proximity to the production frontier from one period to the next, whereas TECHCH depicts how technological change affects efficiency through time. When EFFCH and TECHCH ideas are applied to government policy, EFFCH indicates how efficiently resources are used to achieve a policy's goal. TECHCH, on the other hand, shows changes beyond the policy control such as the introduction of a new programme or operational policy. It should be noted that, EFFCH values bigger than 1 represents an increase in performance, and EFFCH values less than 1 represents a decrease in performance. Also, the TECHCH values bigger than 1 indicate the progress of the technology, and the values less than 1 indicate the regress of the technology.

***Research design***

Figure 1 depicts the conceptual framework in this study. Throughout the policy implementation in Nuklear Malaysia, three inputs and two outputs are selected to analyse the R&D performance of nuclear technology in Nuklear Malaysia from 2011 to 2021. DEA model is used to assess the efficiency of nuclear technology R&D, whilst the Malmquist Index analysis is used to assess the R&D growth over the years and evaluate the impact of the policy intervention towards nuclear technology R&D activities in Nuklear Malaysia such as Malaysian Nuclear Agency Strategic Plan 2012-2020: Strategy and Action Plan, Dasar Sains, Teknologi dan Inovasi Negara (DSTIN) 2013 – 2020, 10$^{th}$ Malaysia Plan 2010-2015 (10$^{th}$ MP) and 11$^{th}$ Malaysia Plan 2016-2020 (11$^{th}$ MP).

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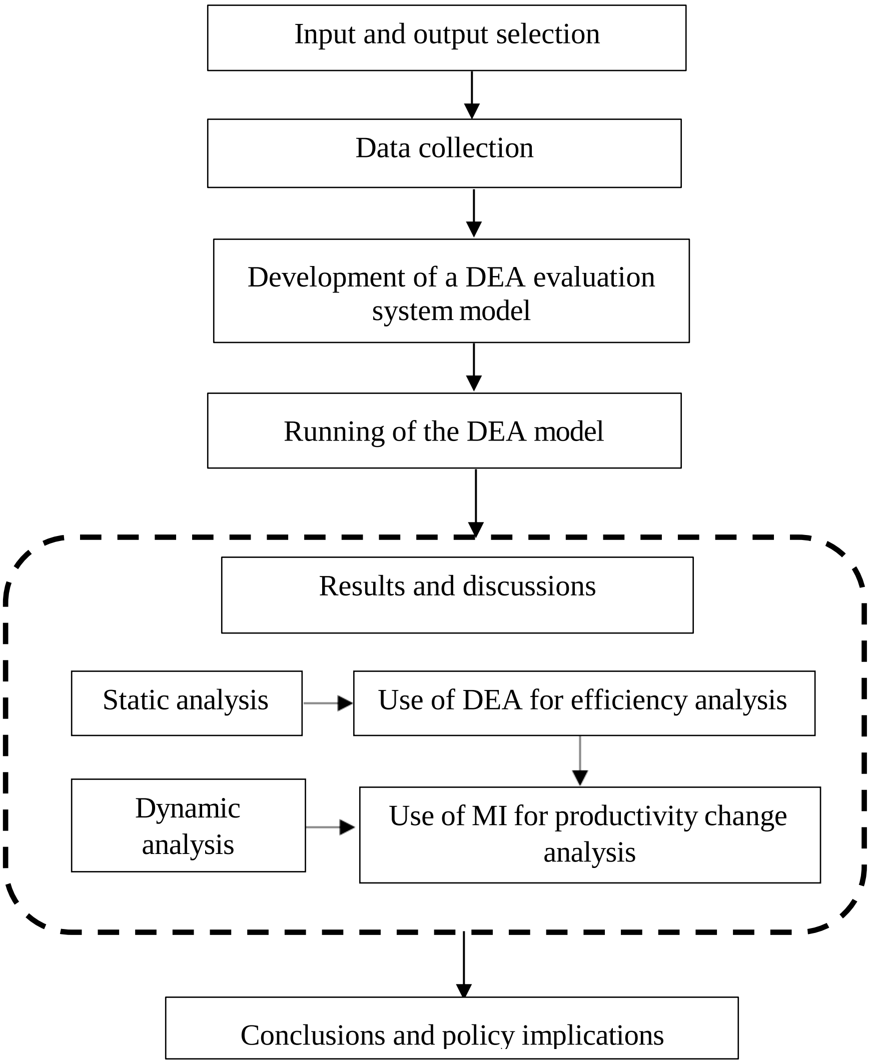


Figure 1: Proposed DEA research framework

***Data collection***

Table 1 shows the inputs and outputs data used collected in this study. In this study, the annual RDC & Development budget (RM Million) and Operating budget (RM Million) are selected as input from the Annual Report of the Malaysian Nuclear Agency from the year 2011-2021. Nuklear Malaysia received a total amount of RM 329.56 million for RDC & Development budget, while RM 864.13 million for the operating budget during this period. The total government funding received for Nuklear Malaysia amounted to RM1193.69 million for 11 years. Revenue (RM Million), no. of R&D products and no. of publications are selected as an output in the study. Income generation through commercialisation activities in Nuklear Malaysia recorded a total of RM125.63 million from 2011-2021. The average total budget ratio between the funding received by Nuklear Malaysia to revenue generated through commercialisation activities in Nuklear Malaysia is around 10.52% from the period 2011-2021. It is noticed that the revenue generation for Nuklear Malaysia decreased in the year 2020 and 2021 during the Covid-19 pandemic season last two years. The number of R&D products produced by Nuklear Malaysia shows an increasing trend over the years. From 2011-2021, the total R&D products produced from Nuklear Malaysia is 722 units including products, patents, procedures, and protocols. Another R&D output used in this study is the number of publications published by researchers of Nuclear Malaysia. Total publications published by Nuclear Malaysia is 5,993 units from 2011-2021, although, in the middle of the study period, the publishing trend shows a decreasing value in 2016 and 2017.

Table 1: Input and output data

| Year | RDC & Development budget (RM Million) | Operating budget (RM Million) | Revenue (RM Million) | No. of R&D products | No. of publications | Budget Ratio |
|---|---|---|---|---|---|---|
| 2011 | 10.20 | 66.21 | 15.78 | 53 | 568 | 20.65% |
| 2012 | 18.43 | 70.67 | 14.61 | 68 | 302 | 16.40% |
| 2013 | 25.42 | 72.90 | 12.45 | 49 | 683 | 12.66% |
| 2014 | 41.81 | 75.89 | 13.24 | 45 | 702 | 11.25% |
| 2015 | 34.07 | 76.77 | 11.41 | 71 | 625 | 10.29% |
| 2016 | 48.29 | 80.15 | 12.62 | 70 | 386 | 9.82% |
| 2017 | 44.50 | 81.50 | 10.38 | 45 | 434 | 8.24% |
| 2018 | 34.12 | 81.93 | 12.06 | 58 | 590 | 10.39% |
| 2019 | 20.87 | 84.79 | 10.43 | 76 | 653 | 9.87% |
| 2020 | 14.08 | 85.90 | 8.11 | 72 | 511 | 8.11% |
| 2021 | 37.75 | 87.40 | 4.54 | 115 | 539 | 3.63% |
| **Total** | **329.56** | **864.13** | **125.63** | **722** | **5993** | **10.52%** |

Table 2 shows the descriptive statistic of input and output data used in this study. The average amount of RDC & Developing a budget is RM29.96 million, with the highest amount being RM48.29 million received in 2016. The trend for operating budget is increasing every year to cover the daily expenses of the organization as well as to pay salaries for the staff. Nuklear Malaysia received the highest Operating budget at RM87.40 million in 2021, with the average amount being RM78.56 million during the study period. The highest revenue generated through commercialisation activities in Nuklear Malaysia is RM15.78 million in 2011, whilst the lowest revenue generated is RM4.54 million in 2021. Nuklear Malaysia produced an amount of 66 R&D products every year with the highest R&D products produced being 115 units in 2021. The highest number of publications published by Nuklear Malaysia is 702 units in 2014, whilst the lowest is at 302 in 2012.

Table 2: Descriptive statistics of input and output data

| | **RDC & Development budget (RM Million)** | **Operating budget (RM Million)** | **Revenue (RM Million)** | **No. of R&D products** | **No. of publications** |
|---|---|---|---|---|---|
| Mean | 29.96 | 78.56 | 11.42 | 66 | 545 |
| St. Deviation | 12.89 | 6.71 | 3.09 | 20 | 127.34 |
| Minimum | 10.20 | 66.22 | 4.54 | 45 | 302 |
| Maximum | 48.29 | 87.40 | 15.78 | 115 | 702 |

## RESULT AND DISCUSSION

### Performance evaluation of nuclear technology R&D activities

Fig. 2 depicts the comparison between the budget received by Nuklear Malaysia and the revenue generated through the commercialisation activities carried out in Nuklear Malaysia from 2011-2021. The operating budget, which covers the salary of staff and daily operations, and maintenance costs is increasing every year since 2011. The increasing operating budgets are mostly due to increasing salary of staff annually including when the staff got promoted in their grade position although the number of staff remain the same. The trend of RDC and development budget which is mainly distributed through the 5-year Malaysia Plan (MP) covers $10^{th}$ MP for 2011-2015 and $11^{th}$ MP for 2016-2020 was not consistent during the study period. It seems that the RDC and development budget is high in the year 2014 during the $10^{th}$ MP and the year 2016 during the $11^{th}$ MP. Both years remark a high RDC and development budget received by Nuklear Malaysia when the Thorium Flagship project entitled Development of Innovative Nuclear Reactor Technology – With the Spin-Off Based on Thorium (FP0214D052 DSTIN) was implemented from 2014 to 2018. The flagship project was implemented under the Dasar Sains, Teknologi Dan Inovasi Negara (DSTIN) 2013 – 2020 due the recommendation from the Jawatankuasa Kajian Penggunaan Torium Sebagai Bahan Asas Dalam Proses Penjanaan Tenaga Nuklear in 2013. However, the revenue generated from the commercialisation activities in Nuklear Malaysia recorded a decreasing trend over the years up to 28.76% compared to 2011 and 2021, especially during the Covid-19 pandemic phase. In addition, the decreasing trend in the revenue generated is observed due to the current efforts made by Nuklear Malaysia that have been made to ensure that research products and activities should be commercialised through technology transfer and licensing to their industrial partners.

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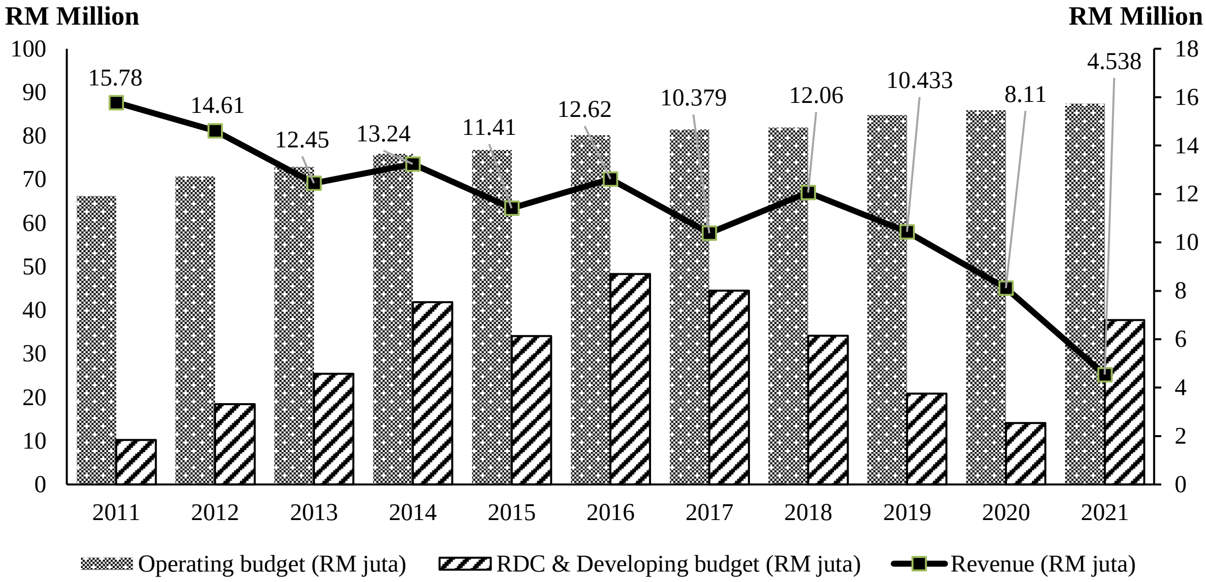


Figure 2: The budget received and revenue generated from 2011-2021

Fig.3 shows the trend of R&D outputs produced by Nuclear Malaysia from 2011-2020. The R&D outputs include innovation awards at national and international levels, number of Intellectual Property Rights (IPR) generated from MOSTI grants or other grants, number of publications, number of products, number of processes and procedures developed and number of potential products for commercialisation generated from Nuklear Malaysia. The total number of R&D products produced by Nuklear Malaysia is 722 units while the number of publications published is 5,993 units from 2011-2020. Although the total publications showed a decreasing trend from 2014 to 2016, the publications activities among Nuklear Malaysia's staff are increased over the years since then. However, the total R&D products including innovation awards, IPR, products, processes, procedures, and potential products for commercialisation show an increasing trend from 2011-2020. This is showing that Nuklear Malaysia's staff are actively conducting R&D activities related to nuclear science and technology concerning the budget received for Nuklear Malaysia either from the annual operating budget or RDC & development budget.

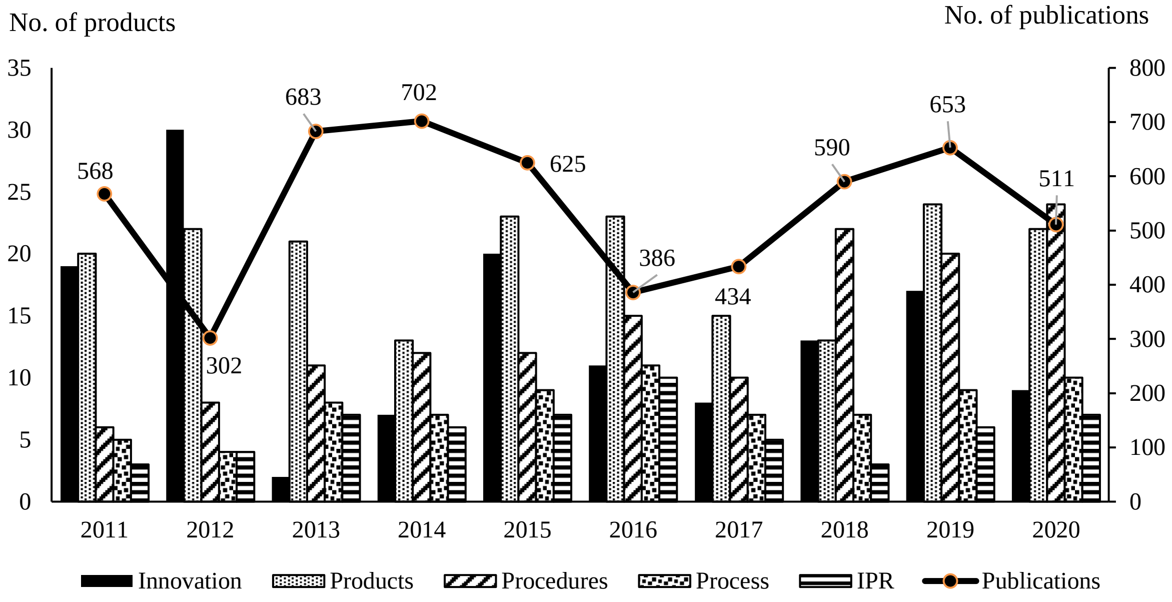


Figure 3: R&D outputs produced by the Malaysian Nuclear Agency from 2011-2020

The summary of efficiency scores using the DEA output-oriented model is shown in Table 3. The output-oriented model is selected in this study to make an inefficient unit to be efficient through the proportional increase of its outputs, while the proportions of the input remain. In this study, the Variable Returns to Scale (VRS) is selected to estimate efficiencies whether an increase or decrease in input or outputs does not result in a proportional change in the outputs or inputs respectively. In most cases, the VRS model is selected by researchers to reflect the real-world issues compared to the CRS model. Table 3 shows that the performance of nuclear technology R&D activities in Nuklear Malaysia is 96.70 per cent from 2011-2021. However, a decreasing trend in the R&D activities in Nuklear Malaysia is highlighted from 2016-2018 due to the decreasing number of R&D outputs produced during this period, especially total publications.

Table 3: Summary of efficiency scores using DEA output-oriented model

| **Year** | **VRS technical efficiency scores** |
|---|---|
| 2011 | 1.000 |
| 2012 | 1.000 |
| 2013 | 1.000 |
| 2014 | 1.000 |
| 2015 | 1.000 |
| 2016 | 0.961 |
| 2017 | 0.739 |
| 2018 | 0.935 |
| 2019 | 1.000 |
| 2020 | 1.000 |
| 2021 | 1.000 |
| **Average** | **0.967** |

**Nuclear technology R&D growth**

Table 4 shows the summary of Malmquist Index analysis during the study period. EFFCH indicates how efficiently resources are used to achieve a specific's goal, whilst TECHCH shows changes beyond the policy control such as the introduction of a new programme or operational policy. The average of EFFCH index remains unchanged during the study period, this means that Nuklear Malaysia efficiently used all resources provided to implement the nuclear technology R&D activities from 2011-2021. However, the average of TECHCH index achieved at 0.917, which means that the technological changes index has decreased at 8.3%. During the study period, the total factor productivity change (TFPCH) for nuclear technology R&D activities in Nuklear Malaysia is 0.917. This is means that the growth of nuclear technology R&D activities in Nuklear Malaysia is decreasing up to 8.3% during 2011-2021. Along the study period, Nuklear Malaysia has efficiently used all resources provided to implement the nuclear technology R&D activities from 2011-2021, however the implementation of the strategic documents as well as the operational policy such as DSTIN and 5-years Malaysia Plan give an impact to the nuclear technology R&D activities to Nuklear Malaysia.

Table 4: Malmquist Index Summary

| Period | EFFCH | TECHCH | PECH | SECH | TFPCH |
|---|---|---|---|---|---|
| 2011-2012 | 1.000 | 0.595 | 1.000 | 1.000 | 0.595 |
| 2012-2013 | 1.000 | 1.070 | 1.000 | 1.000 | 1.070 |
| 2013-2014 | 1.000 | 0.755 | 1.000 | 1.000 | 0.755 |
| 2014-2015 | 1.000 | 1.284 | 1.000 | 1.000 | 1.284 |
| 2015-2016 | 1.000 | 0.679 | 1.000 | 1.000 | 0.679 |
| 2016-2017 | 1.000 | 0.878 | 1.000 | 1.000 | 0.878 |
| 2017-2018 | 1.000 | 1.432 | 1.000 | 1.000 | 1.432 |
| 2018-2019 | 1.000 | 1.338 | 1.000 | 1.000 | 1.338 |
| 2019-2020 | 1.000 | 1.038 | 1.000 | 1.000 | 1.038 |
| 2020-2021 | 1.000 | 0.572 | 1.000 | 1.000 | 0.572 |
| **Average** | **1.000** | **0.917** | **1.000** | **1.000** | **0.917** |

The trends of efficiency changes (EFFCH) index and technological changes (TECHCH) index of nuclear technology R&D is shown in Fig. 4. EFFCH index remains unchanged during the study period with value of 1.000. However, TECHCH index shows different patterns during the study period. TECHCH index decreased in 2011-2012,2013-2014, 2016-2017 and 2020-2021 at value of 0.595, 0.755, 0.878 and 0.572 respectively. The low TECHCH index recorded during the transition period of new policy or strategic plan implementation especially during the 10$^{th}$ MP (2011-2012), DSTIN (2013-2014), 11$^{th}$ MP (2016-2017) and 12$^{th}$ MP (2020-2021). The decreasing value can be translated to the ability of Nuklear Malaysia in adapting the transition process of the new policy or programmes implementation. After the first year of implementation of new policy or strategic plan, TECHCH index increased up to shows an increasing value 2012-2013 (7.0%), 2014-2015 (28.4%), 2017-2018 (43.2%). During the implementation of 12$^{th}$ MP 2016-2020, the average TECHCH index is increased up to 5.16%, compared to implementation of 11$^{th}$ MP period which decreased at 12.34%.

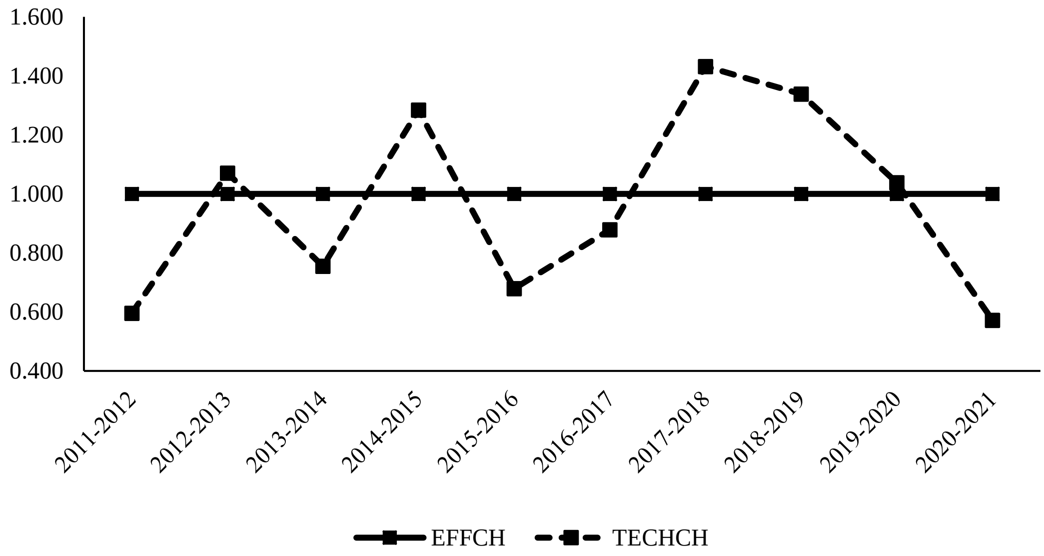


Figure 4: Efficiency changes and technological changes of nuclear technology R&D

Fig.5 shows the total factor productivity changes (TFPCH) index of Malmquist Index of nuclear technology R&D in Nuklear Malaysia from 2011-2021. The nuclear technology R&D growth index in Nuklear Malaysia is mainly affected by technological changes due to policy changes compare to the resources provided since efficiency changes remains the same. The nuclear technology R&D growth index shows different patterns during the study period. The nuclear technology R&D growth index decreased in 2011-2012,2013-2014, 2016-2017 and 2020-2021 at value of 0.595, 0.755, 0.878 and 0.572 respectively. The low nuclear technology R&D growth index recorded during the transition period of new policy or strategic plan implementation especially during the $10^{th}$ MP (2011-2012), DSTIN (2013-2014), $11^{th}$ MP (2016-2017) and $12^{th}$ MP (2020-2021). The decreasing value can be translated to the ability of Nuklear Malaysia in adapting the transition process of the new policy or programmes implementation. After the first year of implementation of new policy or strategic plan, the nuclear technology R&D growth index increased up to shows an increasing value of 2012- 2013 (7.0%), 2014-2015 (28.4%), 2017-2018 (43.2%). It can be concluded that the nuclear technology R&D growth index is increased up to 5.16% during the implementation of $12^{th}$ MP 2016-2020 compared to implementation of $11^{th}$ MP 2011-2015 which decreased at 12.34%.

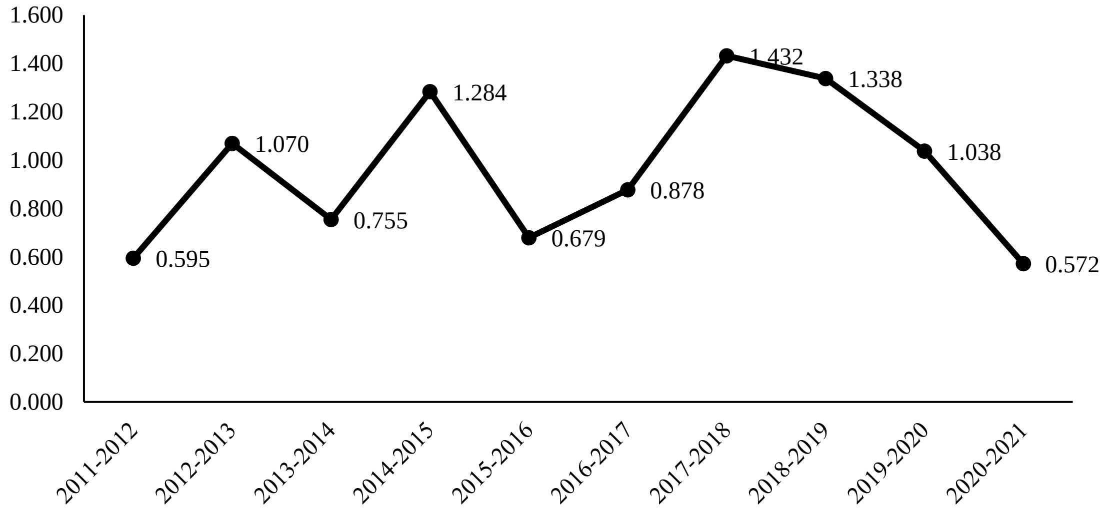


Figure 5: Total factor productivity changes (TFPCH) index of nuclear technology R&D

## DISCUSSIONS

The future economic progress for any country will be driven by the innovation and application of new technologies. The importance of R&D lies there, as it is one category of spending that develops and drives these new technologies. R&D plays an important role in enhancing the capability of research institutes because R&D activities stimulate innovative methods of production, reduce costs and improve product quality. The importance of R&D has become more evident everyday among the factors that directly related to the good economic performance of the emerging countries of 21st centuries. This is necessary because of continuous technology change and development as well as other competitors and the changing preferences of customers everyday which is not possible without an R&D program. Based on the finding from this study, a few recommendations are proposed to ensure the nuclear technology R&D activities in Nuklear Malaysia remains relevance to the national socio- economic development.

Innovation as an output from the R&D activities is a key driver of both economic growth and enhancing the social well-being of a country. Therefore, policies or strategic plan that promote innovation should be top priority for Nuklear Malaysia at any developmental stage. Ministry of Science, Technology and Innovation (MOSTI) can inspire innovation by creating a basic policy for nuclear technology research and development (R&D) to ensure Nuklear Malaysia able to provide appropriate returns to innovative investments. Continued development of emerging technologies, such as internet of things (IoT), artificial intelligence (AI), machine learning (ML), blockchain, cybersecurity and cloud computing, is paving the way for this ongoing R&D investment, as savvy businesses recognize the advantages early adopters have over their competition. Both the stakes and potential gains from investing in new technologies are continuing to increase rapidly alongside the pace of development, driving investment and research in the various sector, while the new technologies will themselves offer new opportunities for innovation.

Nuclear and isotopic techniques can be used as one of the solutions to tackle new global challenges, such as climate change, addressing the growing nutritional and medical demands of an increasing global population and supporting the expansion of industrialization for development. Therefore, the IAEA's platform for scientific collaboration, research and development and training should be grabbed as an opportunity for advancing the nuclear science and technology development to contribute to human wellbeing and sustainable development in Malaysia, particularly in the development areas, including food and agriculture, environmental protection, water management, industrial development, and human health. In addition, technology transfer is a critical ingredient for growth and facilitating it will require addressing the issues such as providing information and capacity building. This is critical for many developing countries, such Malaysia with weak human capital, because if there are lack of engineers and scientists to identify where and how a technology can be applied, there won't be an idea transfer, even if the business environment is in reasonable shape. Therefore, IAEA could assist Nuklear Malaysia in building connections with institutions outside the countries can ease the flow of information and increase countries' awareness of existing technologies.

Technology foresight and road mapping can be used as important tools and method to help keep nuclear science and technology at the forefront of national development, as well as advancing toward a sustainable future. Along with the ongoing innovations and advances in technology, nuclear science and technology continues to contribute to the wellbeing of humankind in the future. The complementary production factors such as qualified personnel, necessary machinery, financing, or managerial capabilities is critical to the complementary production factors necessary for innovation. These factors are also important in identifying and implementing new technologies or undertaking R&D in nuclear technology. In addition, developing countries such as Malaysia, may not have capability of carrying out an R&D project or the human capital to undertake the R&D-focused initiatives, specific policies need to focus on these areas first. Managerial upgrading programmes, which are when an outside expert analyses a company's performance and suggests an improvement plan have been proven to have a large impact on productivity and innovation.

## CONCLUSIONS

This paper has examined the performance and the growth of nuclear technology R&D in Nuklear Malaysia from 2011-2021 using the DEA and MI analysis. The result shows that the performance of nuclear technology R&D in Nuklear Malaysia is 96.70 per cent from 2011-2021. The study shows that nuclear R&D growth decreased by 8.3 per cent for the entire study period. The technological changes decreased at 8.3 per cent, while the efficiency changes remain. The study also found that nuclear technology R&D growth index in Nuklear Malaysia is mainly affected by technological changes due to policy changes compare to the resources provided since efficiency changes remain. The findings of the study help management and officials of Nuklear Malaysia to align the R&D institution's direction to ensure the nuclear technology R&D contribute to the socio-economic development of the country.

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