A PRELIMINARY QUANTITATIVE STUDY ON THE ECONOMIC IMPACTS OF DEPLOYING A NUCLEAR POWER PLANT IN MALAYSIA USING EMPOWER

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Introduction

30th September 2019 marked the sad and disappointing end to Malaysia's latest nuclear ambition when Malaysia Nuclear Power Corporation (MNPC), the Nuclear Energy Programme Implementing Organisation (NEPIO) dedicated to steer the national nuclear power program, was officially closed by the then Pakatan Harapan (PH) government. It was bitterly disappointing because all efforts – financial, manpower, time – invested since 2009 had to be unceremoniously shelved despite the fact that we were already in Phase 2 (decision making phase) of the International Atomic Energy Agency (IAEA)'s infrastructure development program for the newcomer countries [1]. It was heartbreakingly sad when all project outputs – cabinet papers, feasibility study reports, research findings – were blindly ignored by the then PH government as MNPC was not offered any forum to share the lessons learned despite being internationally recognized by the IAEA as a model NEPIO for the newcomer countries. It seemed that the ten-year efforts at preparing Malaysia for a safe and sustainable nuclear power deployment was, simply and completely, cancelled.

What made the decision to disband MNPC more frustrating was the fact that it was chiefly due the promise proclaimed in the 2018 PH Buku Harapan: "the UMNO and Barisan Nasional's efforts to build nuclear power plants will be stopped" (the PH government did just that!). This decision, therefore, felt very politically motivated. To the authors, *this* was neither the right way forward nor the right approach to govern a nation. Any policy decision, especially that concerning a national interest such as our energy of choice, should always be apolitical – free from political pressure and be objectively based on situational merits. As nuclear is the only *proven* low carbon baseload power generation technology, we strongly believe nuclear energy should remain an option for Malaysia despite any election manifesto.

It is upon this conviction that this research paper was prepared: should nuclear option remain on the table; we wondered its direct impacts on our economy. Specifically, we wished to quantitatively evaluate the direct consequences of deploying nuclear power on Malaysia's macroeconomic parameters using the IAEA-developed EMPOWER spreadsheet. It must be noted that the authors are neither economists nor are we pretending to be one; this preliminary study was simply an academic exercise at using EMPOWER and was built on a previous study funded by the MNPC [2]. Values presented in this paper were thus limited by our assumptions and EMPOWER modelling constraints. The results, nonetheless, still offer valuable insights for an informed future decision should Malaysia determine to pursue nuclear power again.

The IAEA's EMPOWER Spreadsheet

EMPOWER (the Extended Input-Output Model for Nuclear Power Plant Impact Assessment) is a Microsoft Excel-based spreadsheet, programmed to quantitatively evaluate impacts of nuclear energy on the key macroeconomic indicators such as employment rate, export levels and the gross domestic product (GDP). EMPOWER was coded in such a way that it would be relatively easy to perform similar assessments on the other types of energy as well. Figure 1 illustrates the graphical use interface of EMPOWER while Figure 2 presents an overview of the mathematical models used in the spreadsheet. Detailed discussions on EMPOWER are available in [3].

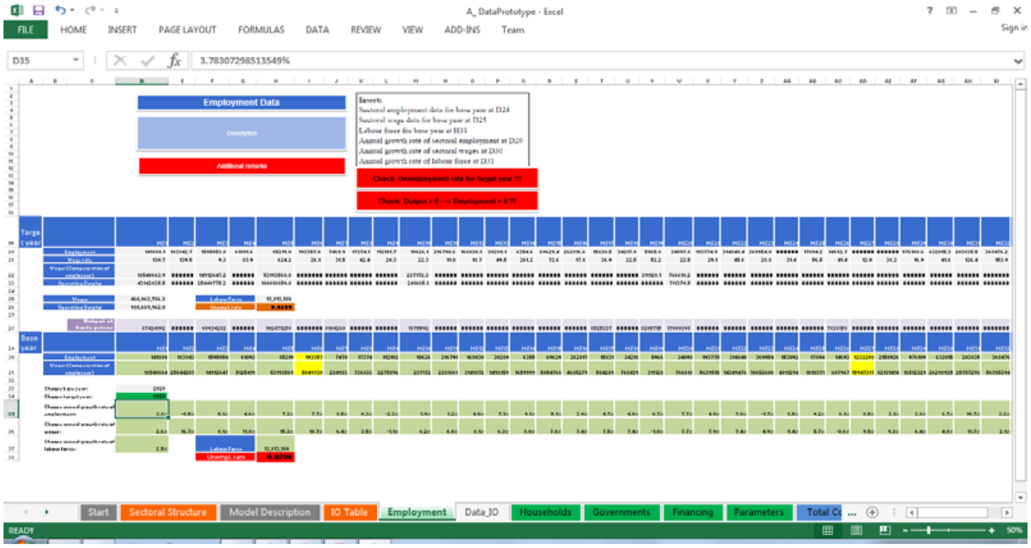
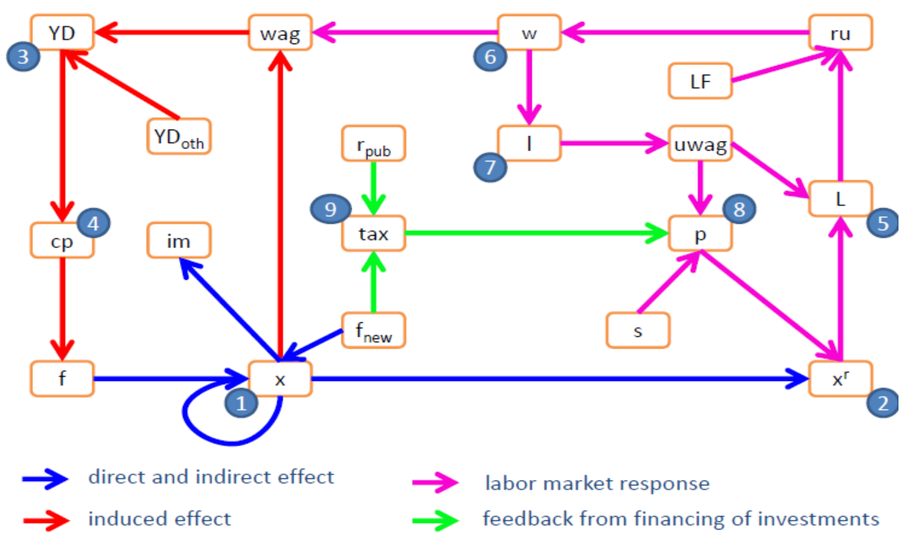


Figure 1: The EMPOWER graphical user interface



(a)

Output (in nominal terms) (1) $\mathbf{x} = \mathbf{A}^d\mathbf{x} + \mathbf{cp} + \mathbf{f}^* + \mathbf{f}^{new}$	Wages (6) $w = \exp(const_w + \beta_{ur}\log(1 - L/LF))$
Output (in real terms) (2) $\mathbf{x}^r = \mathbf{x}/\mathbf{p}$	Unit labour costs (7) $\mathbf{l} = \mathbf{l}_{base}\, w/(0.5 * w_{base} + 0.5 * w)$
Disposable income (3) $YD = \mathbf{l}wf_{w,hh}(1 - t_{hh})\mathbf{x} + \mathbf{s}f_{s,hh}(1 - t_{hh})\mathbf{x} + YD_{oth}$	Prices (8) $\mathbf{p} = \mathbf{p}\mathbf{A}^d + \mathbf{p}^m\mathbf{A}^m + \mathbf{l}w + \mathbf{s} + \mathbf{t}^q$
Consumption (4) $\mathbf{cp} = [\exp(const_{cp} + mpc(\log(YD))]\mathbf{b}^d_{hh}$	Tax rate (9) $t^{new}_{hh} = \frac{r_{pub}\mathbf{i}'\mathbf{f}^{new}}{YD}$
Employment: (5) $L = \mathbf{l}\mathbf{x}^r$	

Four types of multipliers

- direct and indirect effect (equations 1 i 2)
- & induced effect (equations 3 i 4)
- & labor market response (equations 5-8)
- & feedback from financing of investments (equation 9)

(b)

Symbols used:
- x - output;
- cp - household consumption;
- f - final use (excluding household consumption);
- p - output prices;
- w - wage rate (wag/L);
- YD - disposable income (after tax);
- YD_{oth} - non-wage income;
- L - employment;
- LF - labour force;
- t_{hh}^{new} - revenue-neutral tax rate.

Symbols written with variables in the upper or lower index:
- ^{r} - in real terms;
- ^{d} - domestic;
- ^{m} - foreign;
- * - original data;
- ^{base} - in base year.

Parameters:
- l - unit employment (L/x);
- s - unit operational surplus;
- A - Matrix of input-output coefficients;
- t_{hh} - househlod tax rate;
- $f_{s,hh}$ - coefficients for harmonization wages in i-o tables and NA;
- $f_{w,hh}$ - coefficients for harmonization wages in i-o tables and NA;
- *const*- constant term;
- *mpc*- marginal propensity of consumption;
- β_{w} - parameter of wage response to unemployment rate.

Other symbols:
- log - natural logarithm;
- exp - exponential function;
- **i** - unit vector;
- ' - symbol of transposition;

vectors are marked in bold

(c)

Figure 2: *The EMPOWER mathematical models: (a) the schematic program overview, (b) the generic equations for each respective macroeconomic parameter, and (c) a list of nomenclature for the models [3].*

EMPOWER was programmed on a four-level model: (1) ‘Model A’ is the standard input-output program to calculate the direct and indirect effects, (2) ‘Model A + B’ extends ‘Model A’ by capturing the induced effects from private consumption, (3) ‘Model AB + C’ extends ‘Model A + B’ by including the labour market’s responses to supply and demand, and (4) ‘Model ABC + D’ extends ‘Model AB + C’ by also considering the government feedbacks via public-private financing investments [4].

In order to reasonably predict the macro-economic impacts of constructing and operating a nuclear power plant, various economic datasets were inputted into EMPOWER. All data procured for this study were obtained from the Department of Statistic Malaysia (DOSM), Asia Data Library Data Bank, Institute of Labour Market Information and Analysis (ILMIA) database, MNPC archive and online publications.

The main input data used as benchmark for all calculations was the national input-output table, a matrix of domestic and import data for 35 economic sectors in Malaysia. These sectors were specifically selected and grouped based on their direct or indirect influences on local economy. Data on annual employment and wages, as well as growth rates were also needed. This was followed by data of household economic parameters such as annual wages, operating surplus, income tax and average social contribution. As household economic parameters would directly be affected throughout the operation of the nuclear power plant, the datasets were categorized into most favourable, moderately favourable, and least favourable scenarios.

Other financial and economic parameters required by EMPOWER were external financing percentage, marginal propensity of consumption, wage reaction to unemployment rate, and export price elasticity. Total construction cost distribution throughout the 12-year construction period was sourced from MNPC. It should be noted that the simulation results were very sensitive to the currency exchange rates, especially on the distribution of annual construction cost. In addition, the national annual power consumption of other energy sources, as extrapolated from the National Energy Handbook, were also inputted into EMPOWER. It should also be noted that our simulations did not take into account the socio-economic impacts of COVID19 as our study was completed pre-pandemic.

Findings And Discussion

The study assumed a twin NPP unit was to be constructed in the year 2020. Main macroeconomic indicators of interest are GDP, national output, disposable income, and annual employment. Figure 3 displays impacts of constructing the nuclear power plant on the national GDP. 'Model ABC + D' shows the highest and 'Model A' the lowest GDP contribution. This is because 'Model ABC + D' considers wider economic parameters compared to 'Model A'.

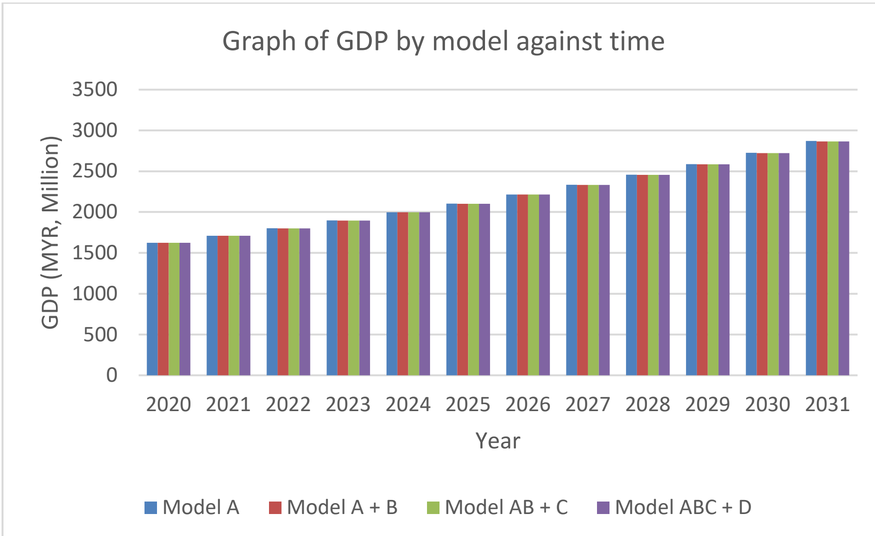


Figure 3: Impacts of an NPP on the national GDP during construction period

Figure 4 shows the national output increment during the construction. National output in this chart represents the sum of GDP and intermediate inputs. Similar to the GDP, output of the nuclear power plant is highest in 'Model ABC + D' and lowest in 'Model A' at the end of the construction year 2031. This is because 'Model A' does not consider factors such as labour market responses, income tax, financing, and investment parameters, which would significantly reduce final output of the nuclear power plant at the end of the construction period.

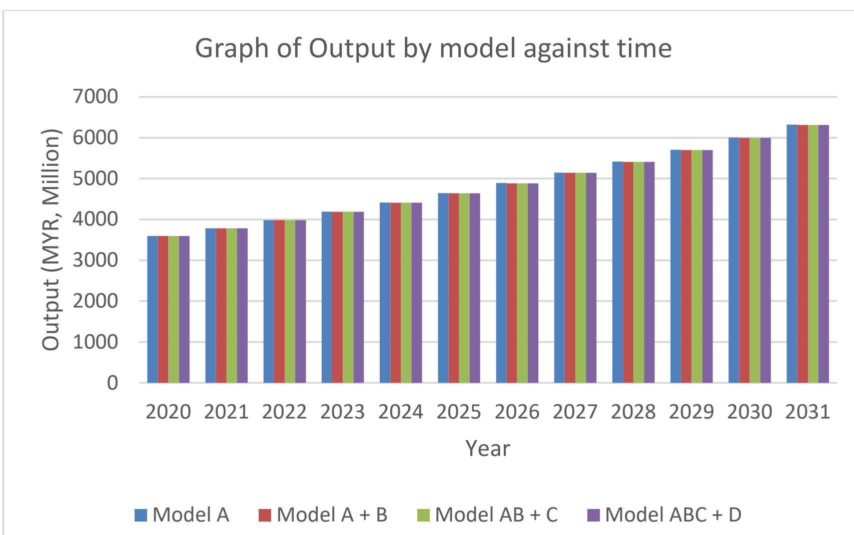


Figure 4: Output of the nuclear power plant during its construction period

Figure 5 shows the national disposable income during the construction period. It should be noted that the disposable income for each model displays similar trend of depreciation throughout. Nevertheless, 'Model A' consistently has the highest disposable income value at the end of the construction period. This is because 'Model A' does not consider factors that directly influence the disposable income such as wages, household expenditure and income tax, which are directly proportional to consumer expenditure per capita and are inversely proportional to the disposable income [6].

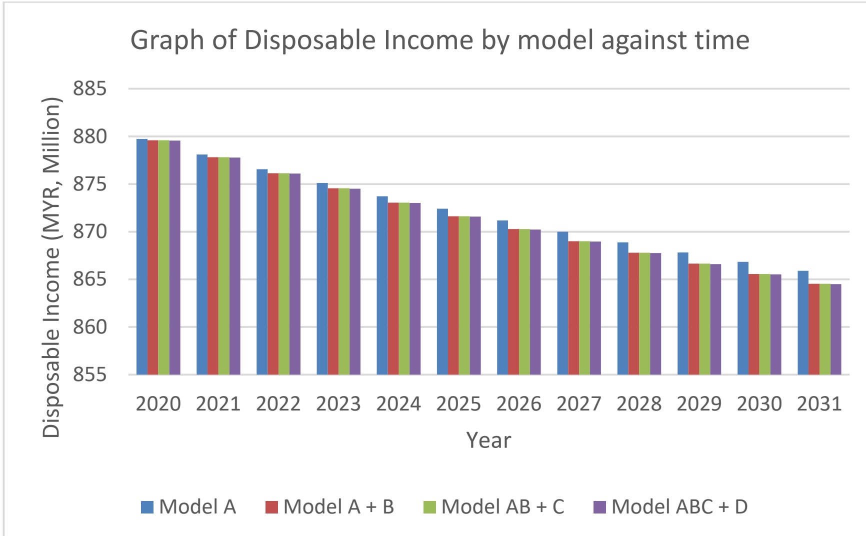


Figure 5: National disposable income throughout the construction period of the power plant

Figure 6 shows annual increment in the local employment during the construction period. 'Model AB + C' and 'Model ABC + D' show constant increments over time, while 'Model A' and 'Model A + B' display some periods of decrement. While demands for skilled labour increase, the required jobs would be highly specific and technical [7]. Skilled labour force would also be necessary to meet any sudden changes in the construction plans and unexpected overnight costs. Since only 'Model AB + C' and 'Model ABC + D' take into account the labour market response, employment by sector and wages by sector, the predicted increment in the employment was expected. On the other hand, 'Model A' and 'Model A + B' predict regressing employment since they exclude the aforementioned considerations.

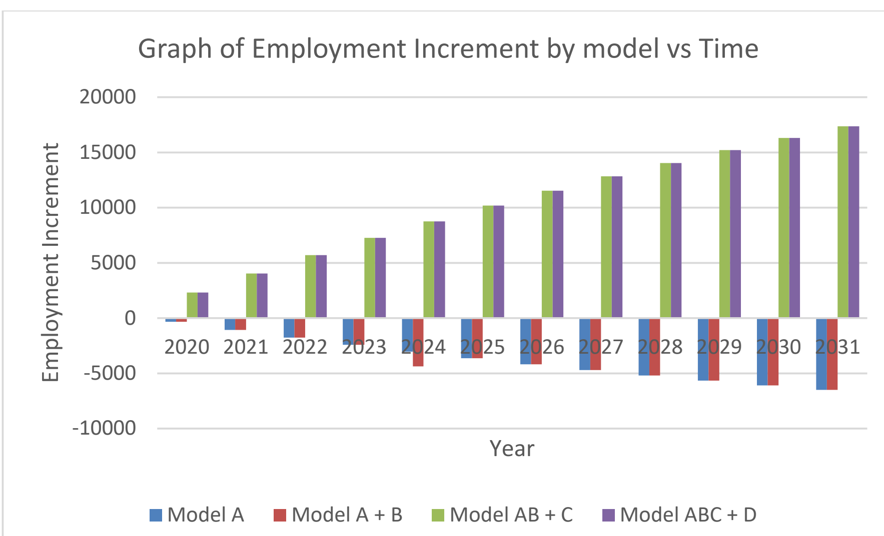


Figure 6: Annual employment during the construction of a nuclear power plant

Figure 7 summarizes the macroeconomic impacts of a nuclear power plant should one commences the operation in the year 2032. 3 scenarios were considered, namely most favourable, moderately favourable, and least favourable. Datasets used to obtain these 3 scenarios were household economic indicators, unique financial parameters, and operation cost output. GDP increment in the most favourable scenario is the highest compared to the other scenarios. It is generally accepted that an investment in nuclear energy would have a positive impact on the GDP due to the interdependence between power consumption and national annual economic growth [8].

Meanwhile, the national output and disposable income in the first year of operation (simulated year 2032) are quite similar in all scenarios since output of the nuclear power plant were about constant [9]. Deviations from the expected annual outcomes may still occur due to scheduled maintenance, outages or reduction in efficiency for a small period of time [10]. The differences in the values between each model would be due to the difference in calculation models; for example, 'Model ABC + D' considers the induced effects of labour market response and feedback from financing and investment, while 'Model AB + C' neglects those feedback from the financing and investment. On the other hand, 'Model A + B' considers the household induced effects such as household income, income tax, social contribution, and operating surplus while 'Model A' uses values directly from the input-output table.

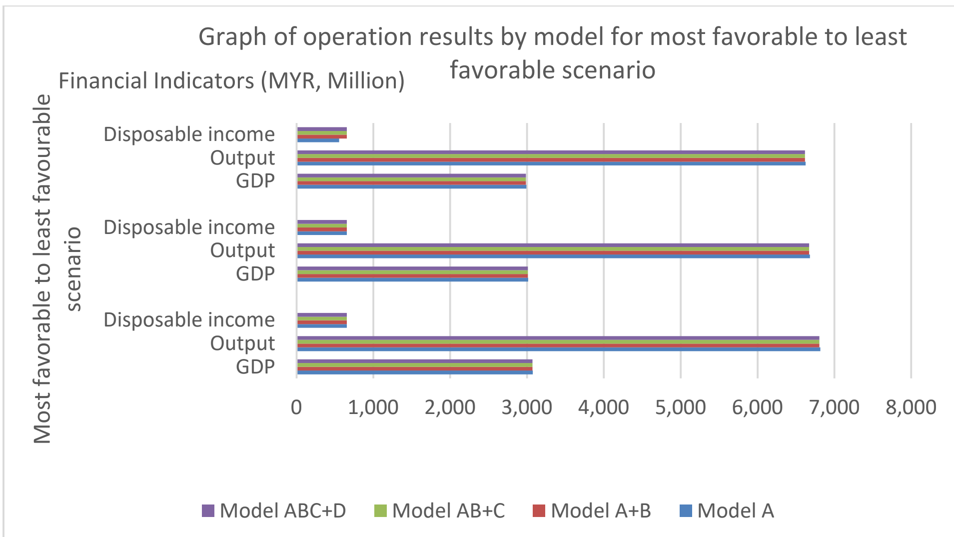


Figure 7: Financial impacts of operating a nuclear power plant in Malaysia

Figure 8 shows impacts on the employment rate by model for the most favourable, moderately favourable, and least favourable scenarios during the first year of plant operation (year 2032). A significant increase in the employment rate can be observed from the last year of construction (year 2031) to the first year of operation (year 2032). This is due to the fact that in order to operate a nuclear power plant, a number of highly qualified personals must be appointed. In the USA, it was found that additional 500,000 jobs per year could be created by just increasing the generation capacity of a nuclear power plant [11].

The predicted values between these scenarios are also quite similar since the simulation was performed during the initial operation period of the nuclear power plant. Nonetheless, 'Model A' displays higher employment rate than 'Model A + B' and 'Model AB + C' because 'Model A' does not consider labour market response, wage reaction to unemployment rate and employment by sector data. These aforementioned parameters negatively affect prospective employment availability due to wage levels and highly specialized technical job requirements. Meanwhile, 'Model ABC + D' predicts an increase in the employment rate because the model takes into account the external financing, export data and investment plans. This reasonably assumes the government and private industries would invest in the nuclear power plants, resulting in the creation of collateral job opportunities such as in the research and development work and consultancy projects.

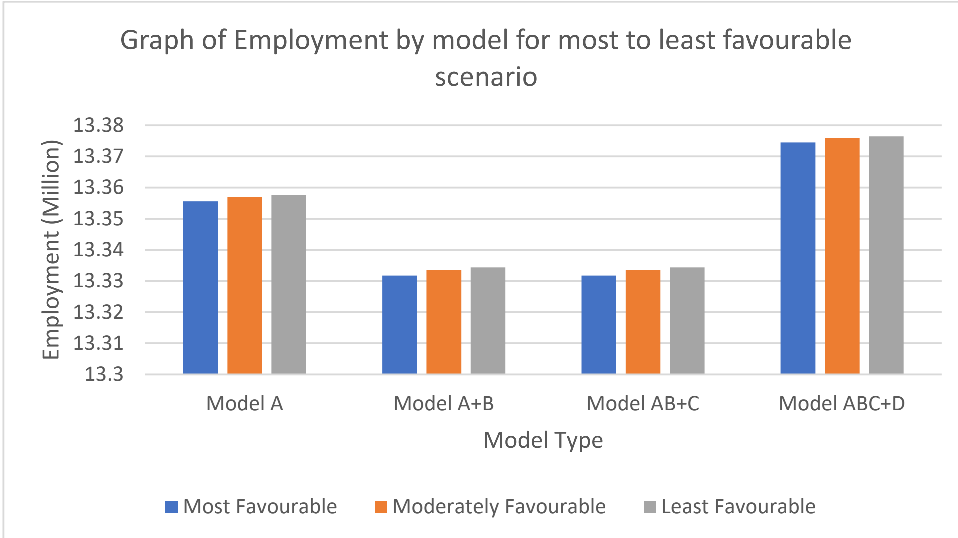


Figure 8: Graph of employment by model for most to least favourable scenario

At the end of the construction period (year 2031), GDP was predicted to be RM2.867 billion, the national output RM6.311 billion, the disposable income RM864.5 million, and the employment opportunity 1.5 million jobs. At the beginning of the operation period (year 2032), twelve years after the start of the construction period (year 2020), the most favourable scenario predicts RM3.071 billion GDP (about +90% from RM1.624 billion in 2020), the national output RM6.806 billion (about +90% RM3.595 billion in 2020) and the disposable income RM654 million (about -25% from RM879 million in 2020).

Conclusion

EMPOWER predicted highly positive impacts of constructing and operating a twin-unit nuclear power station on Malaysia's macro-economic parameters, with almost the doubling of the GDP and national output within the twelve-year period, and significant creations of highly technical and specialized jobs throughout. The study also concluded that the budget of RM31 billion assumed by the previous Malaysia government needs to be revised.

It should be noted that the impacts of deploying nuclear power extend beyond the simulated macroeconomic parameters. Not only embracing nuclear power opens doors for spin-off high-technology industries based on the radiation and clean energy, it also helps cultivate awareness of the highest safety culture. With time, nuclear power can also become our national pride as it helps sow refined appreciation for the scientific knowledge. Most importantly, nuclear power offers the only *proven green* solution to the baseload power generation in order to mitigate the worst consequences of climate change.

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