



## Original Article

# Optimizing the Economic Impact of Increasing Domestic Content through an Interregional Input-Output and Linear Programming Approach: A Case Study of Geothermal Power Plant Investment in the Java-Madura-Bali Region, 2021-2030

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## Abstract:

Investment in the expansion of New and Renewable Energy (NRE) power generation is an essential part of the energy transition program as a commitment to controlling global warming. Based on its characteristics, geothermal power plants (GPP) are the most suitable NRE option to replace coal-fired steam power plants. This commitment is reflected in the Indonesian government's approval of the 2021–2030 Electricity Supply Business Plan (RUPTL) of PT PLN (Persero), which plans the addition of 3.15 GW of geothermal power capacity, with 60.77% located in the Java–Madura–Bali region. However, the domestic content level (Tingkat Komponen Dalam Negeri, TKDN) of geothermal power plant investments remains relatively low, resulting in suboptimal national economic impacts. This study aims to optimize the economic impact of geothermal power plant investment in the Java–Madura–Bali region under combined TKDN enhancement scenarios, using an Interregional Input–Output (IRIO) and Linear Programming approach. The results provide the optimal economic impacts for each scenario as well as target increases in TKDN for each investment cost component. The findings indicate that the initial priority for increasing TKDN in geothermal power plant investment lies in the civil and steel structures cost component.

**Keywords:** MICE Tourism, Event Tourism, Bibliometric Analysis, Co-Occurrence Analysis, Research Trends.

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## Introduction

In 2015, during the Conference of the Parties (COP) 21 in Paris, the Paris Agreement was adopted, introducing, among other initiatives, the Net-Zero Emissions (NZE) program ([UNFCCC, 2015](#)). NZE refers to a condition in which greenhouse gas emissions released into the atmosphere are balanced by their removal. This balance can be achieved through various efforts, including emission reduction measures, enhancement of carbon sinks, and the implementation of offsetting strategies ([Han,](#)

[Bao, Niu, & ur Rehman, 2024](#)).

Indonesia ratified the Paris Agreement through the enactment of Law No. 16 of 2016 on the Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change ([Republik Indonesia, 2019](#)). This regulation serves as the foundation for national development planning, including in the electricity sector and the broader energy transition agenda.

Subsequently, on September 28, 2021, the Ministry of Energy and Mineral Resources (MEMR) of the Republic of Indonesia approved the Electricity Supply Business Plan (RUPTL) of PT PLN (Persero) for the period 2021–2030 through Ministerial Decree No. 188.K/HK.02/MEM.L/2021 [4]. The document outlines plans for the addition of new power generation capacity by type and by region, while also adopting the NZE initiative. This is reflected in the larger proportion of new and renewable energy (NRE) power plants compared to fossil-fuel-based generation. Of the planned 40.57 GW of new generating capacity, 51.58% is allocated to NRE power plants.

The same document also plans the addition of 3.15 GW of geothermal power plants (GPP), of which 60.77% will be located in the Java–Madura–Bali (JMB) region (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2021). Within the JMB power system, geothermal power plants and coal-fired steam power plants serve as baseload generation, operating continuously for 24 hours a day. This is due to their stable and reliable operating characteristics ([PT. PLN \(Persero\) UP2B Jawa Timur, 2021](#)). Therefore, in the context of the energy transition, geothermal power plants represent the most appropriate substitute for coal-fired power plants.

Nevertheless, geothermal power plants require the highest investment costs, as reported by [Hartono D. et al. \(2020\)](#) ([Hartono et al., 2020](#)). At the same time, the domestic content level (Tingkat Komponen Dalam Negeri, TKDN) of geothermal power plant investments remains relatively low, at only 28.9% ([PT. PLN, 2022](#)). This means that geothermal power development currently faces two major challenges: high investment costs and low domestic content. The International Energy Agency (IEA) has explicitly highlighted uncertainty regarding the future of geothermal energy in its report *The Future of Geothermal* ([International Energy Agency, 2024](#)).

This study focuses on the issue of domestic content. With a low TKDN value, only a small portion of geothermal power plant investment circulates within the domestic economy, while the majority flows abroad. Consequently, the domestic economic impact of geothermal investment is also limited. The economic impacts referred to in this study include changes in economic output, gross value added (GVA), household income, and employment, as defined in a research report by the National Research and Innovation Agency (BRIN) in 2022 ([Pusat Pelayanan Teknologi Badan Riset dan Inovasi Nasional, 2022](#)).

Several studies have examined the impacts of TKDN policies. Using Synthetic Control Methods, one study investigated the impact of domestic content requirements on the export of investment components for solar power plants and wind power plants. The results showed no significant correlation between TKDN restrictions and export volumes, except in the cases of China and Spain ([Scheifele, Bräuning, & Probst, 2022](#)). The economic impact of increasing domestic content in wind power plant investments on the UK economy has been analyzed using an input–output approach, revealing a positive correlation between higher domestic content and domestic economic impacts, although it also affected emissions ([Allan, Comerford, Connolly, McGregor, & Ross,](#)

[2020](#)).

In Ghana, an investigation of domestic content requirements for solar power plants and their relationship with technology transfer was conducted through interviews with solar power developers and component manufacturers. The results indicated no significant technology transfer effects from domestic content policies, nor did such policies alter the behavior of solar power developers ([Edze, 2025](#)).

While previous studies have primarily focused on the economic impacts of changes in or restrictions on domestic content levels, this study emphasizes identifying which industrial sectors of geothermal power plant investment components should be prioritized for increasing domestic content in order to achieve optimal economic impacts. To this end, this study employs an Interregional Input–Output (IRIO) framework and Linear Programming (LP) for optimization. For example, if the Government of Indonesia sets a target combined TKDN level of 30% for geothermal power plants by 2027, this study provides guidance on the required increases in domestic content for each geothermal investment component. In this way, the Government of Indonesia can obtain a more precise reference for policy intervention, identifying which industrial sectors should be prioritized to enhance domestic content.

### Literature Review

Studies on the economic impacts of investment have been widely conducted. For example, in 2020, a comparison of the economic impacts of investment across different types of power plants was carried out using a Social Accounting Matrix (SAM) approach ([Hartono et al., 2020](#)).

In 2023, the economic impacts of solar power plant (SPP) and wind power plant (WPP) investments, incorporating the factor of component waste, were analyzed in India using an Input–Output approach. With a target installed capacity of 280 GW, solar power plants were found to have the potential to generate 19.28 thousand tons of component waste ([Prabhu & Mukhopadhyay, 2023](#)). Furthermore, the socio-economic impacts of wind power plant investments during the construction phase and after operation in Brazil were examined using an Interregional Input–Output (IRIO) approach ([Vasconcellos & Couto, 2021](#)). Similarly, in 2022, the economic impacts of solar and wind power plant investments in Japan were analyzed using an IRIO framework ([Matsumoto & Matsumura, 2022](#)).

Beyond the power generation sector, a 2022 study analyzed the socio-economic impacts of the Clean Fuels Project (CFP) and the Al-Zour Refinery Project (ZOR) in Kuwait. Supported by Input–Output analysis, the study found that these two mega projects contributed to a 4.4% increase in gross value added (GVA) and the creation of 200,663 jobs during the construction period ([Nourelfath, Lababidi, & Aldowaisan, 2022](#)). Using an IRIO approach, another study examined the economic and environmental impacts of the shutdown of the Samir oil refinery in Morocco. The results indicated that the refinery closure led to a reduction in economic output amounting to 66,572 million United Arab Emirates Dirhams (DHS) ([Haddad, Araújo, Chawki, El-Mansoum, & Masnaoui, 2023](#)).

The integration of a Multi-Region Input–Output (MRIO) framework with Linear Programming has also been applied to analyze regional economic resilience to disruptions in energy supply, with a case study conducted in China ([He, Ng, & Su, 2019](#)).

These studies indicate that while Input–Output, IRIO, and Linear

Programming approaches have been widely applied to assess economic impacts, their combined use to optimize the economic impacts of increasing domestic content levels (TKDN) remains limited. This study addresses this gap by offering such an integrated approach, thereby contributing to the advancement of knowledge in this field.

## Methods

This section presents the data used in the study and the research methodology in a sequential manner, starting from the calculation of geothermal power plant (GPP) investment costs and targets, followed by the Interregional Input–Output (IRIO) model as the economic system or structure, and finally the Linear Programming (LP) approach employed for optimization.

## Investment Targets, Costs, and Domestic Content of Geothermal Power Plants

According to the Electricity Supply Business Plan (RUPTL) of PT PLN (Persero) for the period 2021–2030, the investment target for geothermal power plants in the Java–Madura–Bali (JMB) region comprises a total of 35 units with an aggregate installed capacity of 1,915 MW ([Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2021](#)). A summary of these targets is presented in Table 1, while detailed planning information is provided in Appendix A. These projects are distributed across five provinces, with the largest number and capacity concentrated in Central Java.

Table 1. Investment Target for Java, Madura, and Bali Regional Geothermal Power Plants

Province	Amount (Unit)	Total Capacity (MW)
Jakarta Special Region	-	-
West Java	11	645
Central Java	13	720
Yogyakarta Special Region	-	-
East Java	6	335
Banten	3	150
Bali	2	65

Source: (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2021) reprocessed

The planned investment costs for PLTP are calculated based on investment cost reference data, using the following equation ([Athanasidou, 2025](#)).

$$C^P = C^R \left( \frac{P^P}{P^R} \right)^{0,7} \quad (1)$$

where  $C^P$  is the investment cost of the planned addition of the PLTP,  $C^R$  is the reference investment cost of the PLTP,  $P^P$  is the planned capacity of the PLTP addition, and  $P^R$  is the reference capacity of the PLTP. The investment cost reference, for the weight and value of the TKDN of the investment cost component, refers to the BRIN

report in 2022 ([Pusat Pelayanan Teknologi Badan Riset dan Inovasi Nasional, 2022](#)).

Table 2. Reference Weight, Total Cost, and Domestic Content Level (TKDN) Value for Geothermal Power Plant Investment

No	Cost Components	Weight ( $B_i^R$ ) (%) <sup>1</sup>	Total Cost 1x50 MW ( $C_T^R$ ) (Milion US\$) <sup>2</sup>	TKDN ( $D_i^R$ ) (%) <sup>1</sup>
1	Balance of Plant (BoP)	16,1		20,0
2	Steamfield Above Ground System (SAGS)	19,1		20,0
3	Generator	10,1		0,0
4	Electric and Instrumentation	15,1		25,0
5	Steam Turbine	14,1		0,0
6	Civil and Steel Structures	8,1		77,0
7	Engineering Services	17,1		68,6
	Total	100,0	200,6	28,9

Source: 1(PT. PLN, 2022) (reprocessed); 2(DJEBTKE-ESDM RI, 2021)

The total investment costs are based on data from the Directorate General of New, Renewable Energy, and Energy Conservation (EBTKE) of the Ministry of Energy and Mineral Resources of the Republic of Indonesia, as presented in Table 2. Based on the table, it can be observed that the largest share of geothermal power plant investment costs is attributed to the Steam and Gas Supply System (SAGS) component, accounting for 19.14%. Meanwhile, the highest domestic content level is found in the civil and steel structures component, with a TKDN value of 77.0%.

The reference weights of the investment cost components are calculated using Equation (2).

$$B_i^R = \frac{C_i^R}{C_T^R} \quad (2)$$

Where  $B_i^R$  denotes the reference weight of the investment cost for the  $i$ -th geothermal power plant component,  $C_i^R$  represents the reference investment cost of the  $i$ -th component,  $C_T^R$  is the reference total investment cost of the geothermal power plant, and  $D_i^R$  denotes the reference domestic content (TKDN) value of the investment cost for the  $i$ -th component.

When the available data consist only of  $B_i^R$  and  $C_T^R$ , the reference investment cost  $C_i^R$  is calculated by transforming Equation (2) into Equation (3).

$$C_i^R = B_i^R C_T^R \quad (3)$$

Then, multiplying  $C_i^R$  by the dollar exchange rate will produce  $C_i^R$  in rupiah. For this study, the dollar exchange rate assumption is Rp. 16,162 per US\$.

## Interregional Input–Output

### 1. Basic Concept of IRIO

The Interregional Input–Output (IRIO) approach is an extension of the conventional Input–Output (IO) analysis, which was first developed by Professor Wassily Leontief in the late 1930s. Both IO and IRIO analyses are based on inter-industry transaction tables. However, IRIO explicitly incorporates transactions across regions, enabling simultaneous analysis of interregional linkages as well as inter-industry relationships (Harmadi, 2023).

		Region R		Region S		Permintaan Akhir	Total Output
		1	2	1	2		
Region R	1	$z_{11}^{RR}$	$z_{12}^{RR}$	$z_{11}^{RS}$	$z_{12}^{RS}$	$Y_1^R$	$X_1^R$
	2	$z_{21}^{RR}$	$z_{22}^{RR}$	$z_{21}^{RS}$	$z_{22}^{RS}$	$Y_2^R$	$X_2^R$
Region S	1	$z_{11}^{SR}$	$z_{12}^{SR}$	$z_{11}^{SS}$	$z_{12}^{SS}$	$Y_1^S$	$X_1^S$
	2	$z_{21}^{SR}$	$z_{22}^{SR}$	$z_{21}^{SS}$	$z_{22}^{SS}$	$Y_2^S$	$X_2^S$
Impor Input Antara		$m_1^R$	$m_2^R$	$m_1^S$	$m_2^S$		
Input Primer		$v_1^R$	$v_2^R$	$v_1^S$	$v_2^S$		
Pendapatan Rumah Tangga		$w_1^R$	$w_2^R$	$w_1^S$	$w_2^S$		
Total Input		$X_1^R$	$X_2^R$	$X_1^S$	$X_2^S$		

Figure 1. Basic Framework of the IRO Table

Source: (Harmadi, 2023) (reprocessed)

The basic framework of an IRIO table with two regions and two industrial sectors is illustrated in Figure 1.  $z_{ij}^{RR}$  represents the output of industrial sector  $i$  in region  $R$  used by industrial sector  $j$  in the same region  $R$ .  $z_{ij}^{RS}$  denotes the output of industrial sector  $i$  in region  $R$  used by industrial sector  $j$  in region  $S$ .  $z_{ij}^{SR}$  represents the output of industrial sector  $i$  in region  $S$  used by industrial sector  $j$  in region  $R$ , while  $z_{ij}^{SS}$  denotes the output of industrial sector  $i$  in region  $S$  used by industrial sector  $j$  within region  $S$ .

$Y_i^R$  represents the final demand of industrial sector  $i$  in region  $R$ , and  $Y_i^S$  represents the final demand of industrial sector  $i$  in region  $S$ .  $X_i^R$  denotes the total output (or total input) of industrial sector  $i$  in region  $R$ , while  $X_i^S$  denotes the total output (or total input) of industrial sector  $i$  in region  $S$ .  $m_j^R$  represents intermediate input imports of industrial sector  $j$  in region  $R$ , and  $m_j^S$  represents intermediate input imports of industrial sector  $j$  in region  $S$ .  $v_j^R$  denotes the gross value added (GVA) of industrial sector  $j$  in region  $R$ , while  $v_j^S$  denotes the GVA of industrial sector  $j$  in region  $S$ .  $w_j^R$  represents household income generated by industrial sector  $j$  in region  $R$ , and  $w_j^S$  represents household income generated by industrial sector  $j$  in region  $S$ .

Based on Figure 1, the input coefficients ( $a$ ) can be calculated using Equations (4) through (7) (Miller & Blair, 2009).

$$a_{ij}^{RR} = \frac{Z_{ij}^{RR}}{X_j^R} \quad (4)$$

$$a_{ij}^{RS} = \frac{Z_{ij}^{RS}}{X_j^S} \quad (5)$$

$$a_{ij}^{SR} = \frac{Z_{ij}^{SR}}{X_j^R} \quad (6)$$

$$a_{ij}^{SS} = \frac{Z_{ij}^{SS}}{X_j^S} \quad (7)$$

Next, in rows, we can write equations 8 to 11 (Harmadi, 2023).

$$a_{11}^{RR}X_1^R + a_{12}^{RR}X_2^R + a_{11}^{RS}X_1^S + a_{12}^{RS}X_2^S + Y_1^R = X_1^R \quad (8)$$

$$a_{21}^{RR}X_1^R + a_{22}^{RR}X_2^R + a_{21}^{RS}X_1^S + a_{22}^{RS}X_2^S + Y_2^R = X_2^R \quad (9)$$

$$a_{11}^{SR}X_1^R + a_{12}^{SR}X_2^R + a_{11}^{SS}X_1^S + a_{12}^{SS}X_2^S + Y_1^S = X_1^S \quad (10)$$

$$a_{21}^{SR}X_1^R + a_{22}^{SR}X_2^R + a_{21}^{SS}X_1^S + a_{22}^{SS}X_2^S + Y_2^S = X_2^S \quad (11)$$

Equation 12, in the form of a matrix partition, can be changed to be expressed as in equation 13.

$$\begin{bmatrix} I - A^{RR} & A^{RS} \\ A^{SR} & I - A^{SS} \end{bmatrix} \begin{bmatrix} X^R \\ X^S \end{bmatrix} = \begin{bmatrix} Y^R \\ Y^S \end{bmatrix} \quad (13)$$

In the end, we will get equations 14 and 15 [22].

$$X = (I - A)^{-1}Y \quad (14)$$

$$X = \alpha Y \quad (15)$$

Where  $A^{RR}$  denotes the partitioned matrix of input coefficients for intraregional transactions within region  $R$ ,  $A^{SS}$  denotes the partitioned matrix of input coefficients for intraregional transactions within region  $S$ ,  $A^{RS}$  represents the partitioned matrix of input coefficients for flows of goods and services from region  $R$  to region  $S$ , and  $A^{SR}$  represents the partitioned matrix of input coefficients for flows of goods and services from region  $S$  to region  $R$ .

$X^R$  denotes the partitioned output vector of region  $R$ , and  $X^S$  denotes the partitioned output vector of region  $S$ .  $Y^R$  denotes the partitioned final demand vector of region  $R$ , and  $Y^S$  denotes the partitioned final demand vector of region  $S$ .  $X$  represents the output vector and  $Y$  represents the final demand vector. Furthermore,  $(I - A)^{-1}$ , denoted as  $\alpha$ , is the Leontief inverse matrix.

Equation (15) expresses the linear relationship between output and final demand. This implies that any change in final demand (for example, an increase or decrease in investment) will be responded to by industrial sectors through

corresponding increases or decreases in their production output, as described in Equation (16).

$$\Delta X = \alpha \Delta Y \quad (16)$$

In this study, PLTP investment is a change or change in final demand  $\Delta Y$ , so that calculations can be made regarding its impact on changes in output  $\Delta X$ .

## 2. Aggregation of the 2016 IRIO Table

In 2021, BPS released the 2016 Interregional Input-Output (IRIO) Table. This table illustrates the economic structure, interregional transactions, and inter-industry transactions in 2016. Total output was 23.70 quadrillion rupiah ([Badan Pusat Statistik Republik Indonesia, 2021b](#)). This study uses this data as the basis for its calculations, as shown in Table 3.

Table 3. Data Sources for IRIO 2016 Table

Calculation of the Impact	Database	Publisher
Output, Gross Value Added, and Household Income	IRIO Indonesia Table of Domestic Transactions Based on Producer Prices by 34 Provinces and 52 Industries in 2016	Central Statistics Agency of the Republic of Indonesia
Labor	IRIO Indonesia Table of Domestic Transactions Based on Producer Prices by 34 Provinces and 17 Business Sectors in 2016	Central Statistics Agency of the Republic of Indonesia
	Number of Workers by Region and Field of Business, 2016	Central Statistics Agency of the Republic of Indonesia

Source: (Badan Pusat Statistik Republik Indonesia, 2016c, 2016b, 2021a)

The use of the IRIO table classified by 17 economic sectors is required because the available employment data are reported according to these 17 sectors. Detailed data for the 52 industrial sectors and the 17 economic sectors are provided in Appendix B. The concordance between the 52 industrial sectors and the 17 economic sectors is presented in Table 4.

The RUPTL of PT PLN (Persero) for the period 2021–2030 is based on five regions. Therefore, the IRIO tables by 34 provinces and 52 industries, as well as the IRIO tables by 34 provinces and 17 economic sectors, need to be aggregated into IRIO tables by five regions and 52 industries, and by five regions and 17 economic sectors. The regional groupings are shown in Table 5.

Table 4. Concordance of 52 Industrial Sectors with 17 Business Fields

17 Business Fields	52 Industrial Sectors
A	I-01, ..., I-07

B	I-08, ..., I-11
C	I-12, ..., I-27
D	I-28 dan I-29
E	I-30
F	I-31
G	I-32 dan I-33
H	I-34, ..., I-39
I	I-40 dan I-41
J	I-42
K	I-43, ..., I-46
L	I-47
MN	I-48
O	I-49
P	I-50
Q	I-51
RSTU	I-52

Source: (Badan Pusat Statistik Republik Indonesia, 2021b) (reprocessed)

Table 5. Grouping of Provinces by Region

Regional	52 Industrial Sectors
Sumatra (SUM)	(1) Aceh, (02) North Sumatra, (03) West Sumatra, (04) Riau, (05) Jambi, (06) South Sumatra, (07) Bengkulu, (08) Lampung, (09) Bangka Belitung Islands, and (10) Riau Islands
Java Madura Bali (JMB)	(11) DKI Jakarta, (12) West Java, (13) Central Java, (14) DI Yogyakarta, (15) East Java, (16) Banten, and (17) Bali
Kalimantan (KAL)	(20) West Kalimantan, (21) Central Kalimantan, (22) South Kalimantan, (23) East Kalimantan, and (24) North Kalimantan
Sulawesi (SUL)	(25) North Sulawesi, (26) Central Sulawesi, (27) South Sulawesi, (28) Southeast Sulawesi, (29) Gorontalo, and (30) West Sulawesi
Maluku, Papua and Nusa Tenggara (MPNT)	(31) Maluku, (32) North Maluku, (33) West Papua, (34) Papua, (18) West Nusa Tenggara, and (19) East Nusa Tenggara

Since the IRIO table consists of 34 provinces and 52 industrial sectors, the size of the intermediate transaction matrix is  $1,768 \times 1,768$ . Aggregating the data into five regions and 52 industrial sectors reduces the size of the intermediate transaction matrix to  $260 \times 260$ . As the number of industrial sectors remains unchanged, with  $i = 1, \dots, 52$  and  $j = 1, \dots, 52$ , the aggregation of intermediate transactions is carried out using Equations (17) through (41) ([FIRMANSYAH, 2006](#)).

Transaction flows from the Sumatra region (SUM):

$$z_{ij}^{SUM-SUM} = \sum_{R=1}^{10} \sum_{S=1}^{10} z_{ij}^{RS} \quad (17)$$

$$z_{ij}^{SUM-JMB} = \sum_{R=1}^{10} \sum_{S=11}^{17} z_{ij}^{RS} \quad (18)$$

$$z_{ij}^{SUM-KAL} = \sum_{R=1}^{10} \sum_{S=20}^{24} z_{ij}^{RS} \quad (19)$$

$$z_{ij}^{SUM-SUL} = \sum_{R=1}^{10} \sum_{S=25}^{30} z_{ij}^{RS} \quad (20)$$

$$z_{ij}^{SUM-MPNT} = \sum_{R=1}^{10} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=1}^{10} \sum_{S=18}^{19} z_{ij}^{RS} \quad (21)$$

Transaction Flow from the Java Madura Bali (JMB) Region:

$$z_{ij}^{JMB-SUM} = \sum_{R=11}^{17} \sum_{S=1}^{10} z_{ij}^{RS} \quad (22)$$

$$z_{ij}^{JMB-JMB} = \sum_{R=11}^{17} \sum_{S=11}^{17} z_{ij}^{RS} \quad (23)$$

$$z_{ij}^{JMB-KAL} = \sum_{R=11}^{17} \sum_{S=20}^{24} z_{ij}^{RS} \quad (24)$$

$$z_{ij}^{JMB-SUL} = \sum_{R=11}^{17} \sum_{S=25}^{30} z_{ij}^{RS} \quad (25)$$

$$z_{ij}^{JMB-MPNT} = \sum_{R=11}^{10} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=11}^{10} \sum_{S=18}^{19} z_{ij}^{RS} \quad (26)$$

Transaction Flow from Kalimantan Region (KAL):

$$z_{ij}^{KAL-SUM} = \sum_{R=20}^{24} \sum_{S=1}^{10} z_{ij}^{RS} \quad (27)$$

$$z_{ij}^{KAL-JMB} = \sum_{R=20}^{24} \sum_{S=11}^{17} z_{ij}^{RS} \quad (28)$$

$$z_{ij}^{KAL-KAL} = \sum_{R=20}^{24} \sum_{S=20}^{24} z_{ij}^{RS} \quad (29)$$

$$z_{ij}^{KAL-SUL} = \sum_{R=20}^{24} \sum_{S=25}^{30} z_{ij}^{RS} \quad (30)$$

$$z_{ij}^{KAL-MPNT} = \sum_{R=20}^{24} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=20}^{24} \sum_{S=18}^{19} z_{ij}^{RS} \quad (31)$$

Transaction Flow from Sulawesi Region (SUL):

$$z_{ij}^{SUL-SUM} = \sum_{R=25}^{30} \sum_{S=1}^{10} z_{ij}^{RS} \quad (32)$$

$$z_{ij}^{SUL-JMB} = \sum_{R=25}^{30} \sum_{S=11}^{17} z_{ij}^{RS} \quad (33)$$

$$z_{ij}^{SUL-KAL} = \sum_{R=25}^{30} \sum_{S=20}^{24} z_{ij}^{RS} \quad (34)$$

$$z_{ij}^{SUL-SUL} = \sum_{R=25}^{30} \sum_{S=25}^{30} z_{ij}^{RS} \quad (35)$$

$$z_{ij}^{SUL-MPNT} = \sum_{R=25}^{30} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=20}^{24} \sum_{S=18}^{19} z_{ij}^{RS} \quad (36)$$

Transaction Flow from the Maluku, Papua and Nusa Tenggara (MPNT) Region:

$$z_{ij}^{MPNT-SUM} = \sum_{R=31}^{34} \sum_{S=1}^{10} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=1}^{10} z_{ij}^{RS} \quad (37)$$

$$z_{ij}^{MPNT-JMB} = \sum_{R=31}^{34} \sum_{S=11}^{17} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=11}^{17} z_{ij}^{RS} \quad (38)$$

$$z_{ij}^{MPNT-KAL} = \sum_{R=31}^{34} \sum_{S=20}^{24} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=20}^{24} z_{ij}^{RS} \quad (39)$$

$$z_{ij}^{MPNT-SUL} = \sum_{R=31}^{34} \sum_{S=25}^{30} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=25}^{30} z_{ij}^{RS} \quad (40)$$

$$z_{ij}^{MPNT-MPNT} = \sum_{R=31}^{34} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=31}^{34} z_{ij}^{RS} + \sum_{R=31}^{34} \sum_{S=18}^{19} z_{ij}^{RS} + \sum_{R=18}^{19} \sum_{S=18}^{19} z_{ij}^{RS} \quad (41)$$

To aggregate the IRIO table by 34 provinces and 17 economic sectors into an IRIO table by five regions and 17 economic sectors, the same equations can be applied, with  $i = 1, \dots, 17$  and  $j = 1, \dots, 17$ .

The next step involves aggregating final demand, output, gross value added (GVA), household income, and inputs. These are calculated using Equations (42) through (61), where  $i = 1, \dots, 52$  for the 52 industrial sectors and  $i = 1, \dots, 17$  for the 17 economic sectors, with the same ranges applying to  $j$  ([FIRMANSYAH, 2006](#)).

Total Final Demand:

$$Y_i^{SUM} = \sum_{R=1}^{10} \sum_{S=1}^{34} Y_i^{RS} \quad (42)$$

$$Y_i^{JMB} = \sum_{R=11}^{17} \sum_{S=1}^{34} Y_i^{RS} \quad (43)$$

$$Y_i^{KAL} = \sum_{R=20}^{24} \sum_{S=1}^{34} Y_i^{RS} \quad (44)$$

$$Y_i^{SUL} = \sum_{R=25}^{30} \sum_{S=1}^{34} Y_i^{RS} \quad (45)$$

$$Y_i^{MPNT} = \sum_{R=31}^{34} \sum_{S=1}^{34} Y_i^{RS} + \sum_{R=18}^{19} \sum_{S=1}^{34} Y_i^{RS} \quad (46)$$

Total Output or Input:

$$X_i^{SUM} = \sum_{R=1}^{10} \sum_{S=1}^{34} X_i^{RS} \quad (47)$$

$$X_i^{JMB} = \sum_{R=11}^{17} \sum_{S=1}^{34} X_i^{RS} \quad (48)$$

$$X_i^{KAL} = \sum_{R=20}^{24} \sum_{S=1}^{34} X_i^{RS} \quad (49)$$

$$X_i^{SUL} = \sum_{R=25}^{30} \sum_{S=1}^{34} X_i^{RS} \quad (50)$$

$$X_i^{MPNT} = \sum_{R=31}^{34} \sum_{S=1}^{34} X_i^{RS} + \sum_{R=18}^{19} \sum_{S=1}^{34} X_i^{RS} \quad (51)$$

Total Gross Value Added (GVA):

$$v_j^{SUM} = \sum_{R=1}^{10} v_j^R \quad (52)$$

$$v_j^{JMB} = \sum_{R=11}^{17} v_j^R \quad (53)$$

$$v_j^{KAL} = \sum_{R=20}^{24} v_j^R \quad (54)$$

$$v_j^{SUL} = \sum_{R=25}^{30} v_j^R \quad (55)$$

$$v_j^{MPNT} = \sum_{R=31}^{34} v_j^R + \sum_{R=18}^{19} v_j^R \quad (56)$$

Total Household Income:

$$w_j^{SUM} = \sum_{R=1}^{10} w_j^R \quad (57)$$

$$w_j^{JMB} = \sum_{R=11}^{17} w_j^R \quad (58)$$

$$w_j^{KAL} = \sum_{R=20}^{24} w_j^R \quad (59)$$

$$w_j^{SUL} = \sum_{R=25}^{30} w_j^R \quad (60)$$

$$w_j^{MPNT} = \sum_{R=31}^{34} w_j^R + \sum_{R=18}^{19} w_j^R \quad (61)$$

Up to this step, the IRIO Table according to 5 Regions and 52 Industrial Sectors 2016 and the IRIO Table according to 5 Regions and 17 Business Fields have been obtained.

### Concordance and Sectoral TKDN Shocks

As discussed in Section 3.1, the investment costs associated with the expansion of geothermal power plants act as the driving factor for changes in final demand, or sectoral shocks, which in turn generate economic impacts. To enable the calculation of these economic impacts, the investment cost components listed in Table 2 must be adjusted or concorded with the 52 industrial sectors and the 17 economic sectors.

The concordance of geothermal power plant investment cost components is conducted through the following steps:

1. Using the Indonesian Standard Industrial Classification (Klasifikasi Baku Lapangan Usaha/KBLI) 2015 [28], identify the appropriate KBLI codes corresponding to each geothermal power plant investment cost component.
2. Based on Step (1), apply the concordance between KBLI 2015 and the 52 industrial sectors ([Badan Pusat Statistik Republik Indonesia, 2021b](#)), so that each geothermal power plant investment cost component is matched with the relevant 52 industrial sectors.
3. Based on Step (2), use Table 4 to further perform concordance with the 17 economic sectors, ensuring that each geothermal power plant investment cost component corresponds to the 17 economic sectors.

After completing these three steps, the geothermal power plant investment cost matrix is obtained, as expressed in Equation (62).

$$C^P = \begin{bmatrix} C_1^P \\ C_2^P \\ \vdots \\ C_i^P \end{bmatrix} \quad (62)$$

Referring back to Figure 1, in addition to domestic intermediate inputs, an industrial sector also requires imported intermediate inputs to produce output. This implies that, when calculating the impact of output changes resulting from changes in

final demand, the components of final demand must first be separated into those spent domestically and those directly imported. This distinction is necessary because the intermediate input transactions recorded in the IRIO table represent domestic transactions only, rather than total transactions.

If the total change in final demand is fully applied as sectoral shocks without this separation, the resulting output changes will be overestimated, as such an approach implicitly assumes that all final demand or investment is spent domestically with no direct imports.

The availability of domestic content (TKDN) data for investment components helps to mitigate this overestimation. TKDN is calculated using Equation (63) ([PT. Biro Klasifikasi Indonesia, 2023](#)).

$$D_i = \frac{KDN_i}{CP_i^T} \times 100\% \quad (63)$$

Where  $KDN_i$  represents the value of the Domestic Content Component used to produce component  $i$ , and  $CP_i^T$  denotes the total cost used to produce component  $i$ .

When a product applies for TKDN certification, it is first subject to verification by the authorized institution. This verification covers raw materials, labor, and equipment or machinery. Therefore, when a product is certified with a TKDN value of 75%, this figure reflects the portion of expenditure that is truly spent domestically and indicates that the product is effectively considered a domestic product.

Consequently, using the domestic content component (KDN) as sectoral shocks in the calculation of economic impacts is a crucial step, as the resulting changes in output accurately represent changes in the national (domestic) economy and avoid overestimation. Referring to Equations (62) and (63), the change in final demand resulting from geothermal power plant investment is calculated using Equation (64).

$$\Delta Y = \begin{bmatrix} C_1^P D_1 \\ C_2^P D_2 \\ \vdots \\ C_i^P D_i \end{bmatrix} = \sum_{i=1}^n C_i^P D_i \quad (64)$$

### Calculation of Economic Impacts

The economic impacts calculated and optimized in this study include changes in output, changes in gross value added (GVA), changes in household income, and changes in employment.

#### 1. Output Changes

Changes in output are directly proportional to changes in final demand, as discussed in the previous section. To simplify the calculation, the output multiplier is used, defined as the column-wise sum of the elements of the Leontief inverse matrix, as expressed in Equation (65) ([Miller & Blair, 2009](#)).

$$O_j^R = \sum_{i=1}^n \alpha_{ij}^R \quad (65)$$

Where  $O_j^R$  denotes the output multiplier of sector  $j$  in region  $R$ , and  $\alpha_{ij}^R$

represents the elements of the Leontief inverse matrix for sector  $j$  in region  $R$ .

The output multiplier indicates that a change in final demand in sector  $j$  within region  $R$  will result in a total output change equal to  $O_j^R$  (Miller & Blair, 2009). Accordingly, the total change in output due to a change in final demand in region  $R$ , denoted as  $\Delta X_T^R$ , can be obtained by multiplying  $O_j^R$  by the change in final demand  $\Delta Y_i^R$ , as expressed in Equation (66).

$$\Delta X_T^R = [O_1^R \quad O_2^R \quad \dots \quad O_j^R] \begin{bmatrix} \Delta Y_1^R \\ \Delta Y_2^R \\ \vdots \\ \Delta Y_i^R \end{bmatrix} \quad (66)$$

$$\Delta X_T^R = O_1^R \Delta Y_1^R + O_2^R \Delta Y_2^R + \dots + O_j^R \Delta Y_i^R \quad (67)$$

$$\Delta X_T^R = \sum_{j=1}^n O_j^R \Delta Y_i^R, \text{ di mana } i = j \quad (68)$$

Equation 66 will produce a scalar number, namely the total change in output, as in equation 67. Finally, we can write an equation to calculate the change in output, as in equation 68.

This research is based on five regions, and there was a change in final demand in the JMB region only, namely geothermal power plant investment. Therefore, referring to equation 68, we can calculate the change in output in each region using equations 69 through 74.

$$\Delta X_{T-JMB}^{SUM} = \sum_{j=1}^n O_j^{SUM-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (69)$$

$$\Delta X_{T-JMB}^{JMB} = \sum_{j=1}^n O_j^{JMB-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (70)$$

$$\Delta X_{T-JMB}^{KAL} = \sum_{j=1}^n O_j^{KAL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (71)$$

$$\Delta X_{T-JMB}^{SUL} = \sum_{j=1}^n O_j^{SUL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (72)$$

$$\Delta X_{T-JMB}^{MPNT} = \sum_{j=1}^n O_j^{MPNT-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (73)$$

$$\Delta X_{T-JMB} = \sum_{j=1}^n O_j^{T-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (74)$$

Where  $\Delta X_{T-JMB}^{SUM}$  denotes the total change in output occurring in the Sumatra region as a result of changes in final demand in the Java–Madura–Bali (JMB) region.  $O_j^{SUM-JMB}$  represents the output multiplier of industrial sector  $j$  originating from the Sumatra region and used in the JMB region.  $\Delta Y_i^{JMB}$  denotes the change in final demand of sector  $i$  in the JMB region.

$\Delta X_{T-JMB}$  represents the total national output change resulting from changes in final demand in the JMB region, and  $O_j^{T-JMB}$  denotes the total output multiplier of industrial sector  $j$  associated with the JMB region.

Similar definitions apply to

$$\Delta X_{T-JMB}^{JMB}, \Delta X_{T-JMB}^{KAL}, \Delta X_{T-JMB}^{SUL}, \Delta X_{T-JMB}^{MPNT}, O_j^{JMB-JMB}, O_j^{KAL-JMB}, O_j^{SUL-JMB}, \text{ and } O_j^{MPNT-JMB}.$$

## 2. Changes in Gross Value Added

Gross Value Added (GVA) or Primary Input is a component of industrial sector input, data for which is available in the IRIO Table, in a separate row at the bottom. The proportion or comparison between the total GVA and total input is called the GVA Coefficient. For each industrial sector in each region, the GVA Coefficient can be calculated using equation 75 ([Miller & Blair, 2009](#)).

$$V_{Rj}^R = \frac{v_j^R}{X_j^R} \quad (75)$$

Where  $V_{Rj}^R$  is the coefficient of the NTB of industrial sector  $j$  in region  $R$ ,  $v_j^R$  is the value of the NTB of industrial sector  $j$  in region  $R$ , and  $X_j^R$  is the total input of industrial sector  $j$  in region  $R$ .

Equation 75 means that if there is a change in output, the NTB value will also change, linearly with the NTB coefficient. Meanwhile, changes in output itself change when there is final demand. Therefore, changes in the NTB will also occur when there is a change in final demand. Here, the logic of the Output Multiplier can also be applied to obtain or calculate the NTB Multiplier, as in equations 76 to 80 ([Miller & Blair, 2009](#)).

$$v_j^R = V_{Rj}^R X_j^R \quad (76)$$

$$\Delta v_j^R = V_{Rj}^R \Delta X_j^R \quad (77)$$

$$\Delta V = \begin{bmatrix} v_R^{RR} & v_R^{RS} \\ v_R^{SR} & v_R^{SS} \end{bmatrix} \begin{bmatrix} \alpha^{RR} & \alpha^{RS} \\ \alpha^{SR} & \alpha^{SS} \end{bmatrix} \begin{bmatrix} \Delta Y^R \\ \Delta Y^S \end{bmatrix} \quad (78)$$

$$\Delta V = \begin{bmatrix} v_m^{RR} & v_m^{RS} \\ v_m^{SR} & v_m^{SS} \end{bmatrix} \begin{bmatrix} \Delta Y^R \\ \Delta Y^S \end{bmatrix} \quad (79)$$

$$V_{mj}^R = \sum_{i=1}^n v_{mij}^R \quad (80)$$

Where  $\Delta v_j^R$  denotes the total change in gross value added (GVA) resulting from changes in the output of industrial sector  $j$  in region  $R$ , and  $\Delta X_j^R$  represents the total change in output of industrial sector  $j$  in region  $R$ .  $v_R^{RR}$ ,  $v_R^{RS}$ ,  $v_R^{SR}$ , and  $v_R^{SS}$  denote the partitioned matrices of the diagonal GVA coefficient matrix.  $\alpha^{RR}$ ,  $\alpha^{RS}$ ,  $\alpha^{SR}$ , and  $\alpha^{SS}$  represent the partitioned matrices of the Leontief inverse.  $\Delta Y^R$  and  $\Delta Y^S$  are the partitioned matrices of changes in final demand, and  $\Delta V$  denotes the matrix of changes in GVA.

$v_m^{RR}$ ,  $v_m^{RS}$ ,  $v_m^{SR}$ , and  $v_m^{SS}$  represent the partitioned matrices resulting from the multiplication of the diagonal GVA coefficient matrix with the Leontief inverse

matrix.  $v_{mij}^R$  denotes an element of the matrix resulting from the multiplication of the diagonal GVA coefficient matrix with the Leontief inverse in region  $R$ .  $V_{mj}^R$  is the GVA multiplier of industrial sector  $j$  in region  $R$ .

The logic of Equations (66) through (68) can also be applied in the context of changes in GVA, yielding Equations (81) through (83).

$$\Delta V_T^R = [V_{m1}^R \quad V_{m2}^R \quad \dots \quad V_{mj}^R] \begin{bmatrix} \Delta Y_1^R \\ \Delta Y_2^R \\ \vdots \\ \Delta Y_i^R \end{bmatrix} \quad (81)$$

$$\Delta V_T^R = V_{m1}^R \Delta Y_{1_1}^R + V_{m2}^R \Delta Y_2^R + \dots + V_{mj}^R \Delta Y_i^R \quad (82)$$

$$\Delta V_T^R = \sum_{j=1}^n V_{mj}^R \Delta Y_i^R, \text{ where } i = j \quad (83)$$

Where  $\Delta V_T^R$  denotes the total change in gross value added (GVA) resulting from changes in final demand in region  $R$ .

Once again, the logic of regional output changes (Equations 69 through 74) is applied to calculate regional GVA changes arising from changes in final demand in the Java–Madura–Bali region. This leads to the formulation of Equations (84) through (89).

$$\Delta V_{T-JMB}^{SUM} = \sum_{j=1}^n V_{mj}^{SUM-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (84)$$

$$\Delta V_{T-JMB}^{JMB} = \sum_{j=1}^n V_{mj}^{JMB-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (85)$$

$$\Delta V_{T-JMB}^{KAL} = \sum_{j=1}^n V_{mj}^{KAL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (86)$$

$$\Delta V_{T-JMB}^{SUL} = \sum_{j=1}^n V_{mj}^{SUL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (87)$$

$$\Delta V_{T-JMB}^{MPNT} = \sum_{j=1}^n V_{mj}^{MPNT-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (88)$$

$$\Delta V_{T-JMB} = \sum_{j=1}^n V_{mj}^{T-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (89)$$

Where  $\Delta V_{T-JMB}^{SUM}$  denotes the total change in gross value added (GVA) occurring in the Sumatra region as a result of changes in final demand in the Java–Madura–Bali (JMB) region.  $V_{mj}^{SUM-JMB}$  represents the GVA multiplier of industrial sector  $j$  originating from the Sumatra region and used in the JMB region.  $\Delta Y_i^{JMB}$  denotes the change in final demand of sector  $i$  in the JMB region.

$\Delta V_{T-JMB}$  represents the total national GVA change resulting from changes in final demand in the JMB region, and  $V_{mj}^{T-JMB}$  denotes the total GVA multiplier of

industrial sector  $j$  associated with the JMB region.

Similar definitions apply to  $\Delta V_{T-JMB}^{JMB}$ ,  $\Delta V_{T-JMB}^{KAL}$ ,  $\Delta V_{T-JMB}^{SUL}$ ,  $\Delta V_{T-JMB}^{MPNT}$ ,  $V_{mj}^{JMB-JMB}$ ,  $V_{mj}^{KAL-JMB}$ ,  $V_{mj}^{SUL-JMB}$ , and  $V_{mj}^{MPNT-JMB}$ .

### 3. Changes in Household Income

Household income is a component of primary inputs or gross value added (GVA). Therefore, when GVA changes as a result of changes in final demand, household income will also change accordingly. Data on household income are already provided in the IRIO table.

The logic of GVA coefficients and GVA multipliers can be applied to calculate household income coefficients, household income multipliers, and changes in household income, as expressed in Equations (90) through (92) (Miller & Blair, 2009).

$$W_{Rj}^R = \frac{w_j^R}{X_j^R} \quad (90)$$

$$\Delta W = \begin{bmatrix} w_m^{RR} & w_m^{RS} \\ w_m^{SR} & w_m^{SS} \end{bmatrix} \begin{bmatrix} \Delta Y^R \\ \Delta Y^S \end{bmatrix} \quad (91)$$

$$W_{mj}^R = \sum_{i=1}^n w_{mij}^R \quad (92)$$

$$\Delta W_T^R = \sum_{j=1}^n W_{mj}^R \Delta Y_i^R, \text{ di mana } i = j \quad (93)$$

Where  $W_{Rj}^R$  denotes the household income coefficient of industrial sector  $j$  in region  $R$ ,  $w_j^R$  represents household income generated by industrial sector  $j$  in region  $R$ , and  $X_j^R$  denotes the total input of industrial sector  $j$  in region  $R$ .  $\Delta W$  represents the matrix of changes in household income.

$w_m^{RR}$ ,  $w_m^{RS}$ ,  $w_m^{SR}$ , and  $w_m^{SS}$  denote the partitioned matrices resulting from the multiplication of the diagonal household income coefficient matrix with the Leontief inverse matrix.  $w_{mij}^R$  represents an element of the matrix resulting from the multiplication of the diagonal household income coefficient matrix with the Leontief inverse in region  $R$ .  $W_{mj}^R$  denotes the household income multiplier of industrial sector  $j$  in region  $R$ .

Finally,  $\Delta W_T^R$  denotes the total change in household income resulting from changes in final demand in region  $R$ . The changes in household income resulting from changes in final demand in the Java–Madura–Bali region are calculated using Equations (94) through (99).

$$\Delta W_{T-JMB}^{SUM} = \sum_{j=1}^n W_{mj}^{SUM-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (94)$$

$$\Delta W_{T-JMB}^{JMB} = \sum_{j=1}^n W_{mj}^{JMB-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (95)$$

$$\Delta W_{T-JMB}^{KAL} = \sum_{j=1}^n W_{mj}^{KAL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (96)$$

$$\Delta W_{T-JMB}^{SUL} = \sum_{j=1}^n W_{mj}^{SUL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (97)$$

$$\Delta W_{T-JMB}^{MPNT} = \sum_{j=1}^n W_{mj}^{MPNT-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (98)$$

$$\Delta W_{T-JMB} = \sum_{j=1}^n W_{mj}^{T-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (99)$$

Where  $\Delta W_{T-JMB}^{SUM}$  denotes the total change in household income occurring in the Sumatra region as a result of changes in final demand in the Java–Madura–Bali (JMB) region.  $W_{mj}^{SUM-JMB}$  represents the household income multiplier of industrial sector  $j$  originating from the Sumatra region and used in the JMB region.  $\Delta Y_i^{JMB}$  denotes the change in final demand of sector  $i$  in the JMB region.

$\Delta W_{T-JMB}$  represents the total national change in household income resulting from changes in final demand in the JMB region, and  $W_{mj}^{T-JMB}$  denotes the total household income multiplier of industrial sector  $j$  associated with the JMB region.

Similar definitions apply to  $\Delta W_{T-JMB}^{JMB}$ ,  $\Delta W_{T-JMB}^{KAL}$ ,  $\Delta W_{T-JMB}^{SUL}$ ,  $\Delta W_{T-JMB}^{MPNT}$ ,  $W_{mj}^{JMB-JMB}$ ,  $W_{mj}^{KAL-JMB}$ ,  $W_{mj}^{SUL-JMB}$ , and  $W_{mj}^{MPNT-JMB}$ .

#### 4. Changes in Employment

Employment data are not directly available in the IRIO table. Therefore, external data are required. In this study, employment data from Statistics Indonesia (BPS) in the form of the number of employed persons by 34 provinces and 17 economic sectors for the year 2016 were used. For this reason, the employment analysis utilizes the IRIO table classified by 17 economic sectors. To ensure consistency with the five-region framework, the data were aggregated accordingly, with the results presented in Table 6.

Table 6. Number of Workers by 5 Regions and 17 Business Fields (Thousand People)

Business Field	Regional				
	SUM	JMB	KAL	SUL	MPNT
A	2.582,9	4.751,8	506,8	562,0	316,7
B	278,1	294,8	302,3	82,8	48,9
C	1.044,2	8.707,7	232,9	236,1	112,4
D	58,1	122,7	13,0	18,4	16,9
E	32,4	102,9	11,7	10,2	9,3
F	1.140,6	4.900,6	324,1	479,2	300,3
G	1.008,2	4.727,7	351,9	273,5	190,3
H	535,4	1.417,2	161,1	154,6	140,0
I	264,6	1.399,0	76,9	72,0	54,8
J	83,0	332,6	18,8	23,2	14,5

K	214,9	1.277,8	73,0	74,6	50,3
L	14,9	255,2	2,8	3,9	0,6
MN	117,3	760,5	67,2	42,1	31,8
O	1.236,7	2.232,0	414,5	567,3	536,0
P	1.473,8	3.055,3	409,2	528,0	446,0
Q	400,1	859,1	103,2	160,5	115,0
RSTU	609,2	2.828,2	151,7	146,5	134,0

Source: (Badan Pusat Statistik Republik Indonesia, 2016a) reprocessed

By adding the data from Table 6 to the IRIO Table, labor force analysis can be performed, as can NTB and Household Income. Referring to the logic of NTB and Household Income, the Labor Force Coefficient, Labor Force Multiplier, and Labor Force Change can be calculated using equations 100 to 103 (Miller & Blair, 2009).

$$L_{Rj}^R = \frac{l_j^R}{X_j^R} \quad (100)$$

$$\Delta L = \begin{bmatrix} l_m^{RR} & l_m^{RS} \\ l_m^{SR} & l_m^{SS} \end{bmatrix} \begin{bmatrix} \Delta Y^R \\ \Delta Y^S \end{bmatrix} \quad (101)$$

$$L_{mj}^R = \sum_{i=1}^n l_{mij}^R \quad (102)$$

$$\Delta L_T^R = \sum_{j=1}^n L_{mj}^R \Delta Y_i^R, \text{ where } i = j \quad (103)$$

Where  $L_{Rj}^R$  is the labor coefficient of industrial sector  $j$  in region  $R$ , measured in thousands of workers per trillion rupiah;  $l_j^R$  denotes the number of workers in industrial sector  $j$  in region  $R$ , measured in thousands of persons; and  $X_j^R$  represents the total input of industrial sector  $j$  in region  $R$ , measured in trillion rupiah.

$\Delta L$  is the matrix of changes in employment.

The matrices  $l_m^{RR}$ ,  $l_m^{RS}$ ,  $l_m^{SR}$ , and  $l_m^{SS}$  are partitioned matrices resulting from the multiplication of the diagonal matrix of labor coefficients and the Leontief inverse matrix.

$l_{mij}^R$  is an element of the matrix resulting from the multiplication of the diagonal labor coefficient matrix and the Leontief inverse matrix in region  $R$ .  $L_{mj}^R$  is the labor multiplier of industrial sector  $j$  in region  $R$ . Furthermore,  $\Delta L_T^R$  represents the total change in employment resulting from changes in final demand in region  $R$ .

Subsequently, changes in employment due to changes in final demand in the Java–Madura–Bali region are calculated using Equations 104 to 109.

$$\Delta L_{T-JMB}^{SUM} = \sum_{j=1}^n L_{mj}^{SUM-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (104)$$

$$\Delta L_{T-JMB}^{JMB} = \sum_{j=1}^n L_{mj}^{JMB-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (105)$$

$$\Delta L_{T-JMB}^{KAL} = \sum_{j=1}^n L_{mj}^{KAL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (106)$$

$$\Delta L_{T-JMB}^{SUL} = \sum_{j=1}^n L_{mj}^{SUL-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (107)$$

$$\Delta L_{T-JMB}^{MPNT} = \sum_{j=1}^n L_{mj}^{MPNT-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (108)$$

$$\Delta L_{T-JMB} = \sum_{j=1}^n L_{mj}^{T-JMB} \Delta Y_i^{JMB}, \text{ where } i = j \quad (109)$$

Where  $\Delta L_{T-JMB}^{SUM}$  is the total change in employment occurring in the Sumatra region as a result of changes in final demand in the Java–Madura–Bali region.  $L_{mj}^{SUM-JMB}$  is the labor multiplier of industrial sector  $j$  originating from the Sumatra region and utilized in the Java–Madura–Bali region.  $\Delta Y_i^{JMB}$  denotes the change in final demand of sector  $iii$  in the Java–Madura–Bali region.

$\Delta L_{T-JMB}$  represents the total national change in employment resulting from changes in final demand in the Java–Madura–Bali region. Meanwhile,  $L_{mj}^{T-JMB}$  is the total labor multiplier of industrial sector  $j$  for the Java–Madura–Bali region.

Similar definitions apply to  $\Delta L_{T-JMB}^{JMB}$ ,  $\Delta L_{T-JMB}^{KAL}$ ,  $\Delta L_{T-JMB}^{SUL}$ ,  $\Delta L_{T-JMB}^{MPNT}$ ,  $L_{mj}^{JMB-JMB}$ ,  $L_{mj}^{KAL-JMB}$ ,  $L_{mj}^{SUL-JMB}$ , and  $L_{mj}^{MPNT-JMB}$ .

### Linear Programming Optimization

Linear Programming (LP) is an optimization technique that has been widely used in decision-making and planning processes.

The main components of optimization using LP are the objective function, decision variables, and constraints. The objective function is the function to be optimized, either maximized or minimized. Decision variables are a set of variables whose values are to be determined in order to achieve the optimal value of the objective function. Constraints represent the limitations imposed on both the objective function and the decision variables.

The optimization of economic impacts can be rationalized as follows:

- a. Based on Section 3.4, changes in output, value added (VA), household income, and employment are functions of changes in final demand  $\Delta Y$ . Therefore, optimization can be performed by treating  $\Delta Y$  as the decision variables.
  - b. Changes in final demand, as expressed in Equation (64), are functions of the Domestic Component Level (TKDN) values.
  - c. Accordingly, changes in output, value added, household income, and employment can be optimized by using TKDN values as the decision variables.
1. Optimization Scenario

The optimization scenario was implemented by using the combined TKDN

value as a constraint, rationalizing that this combined TKDN will be the target or step for increasing the TKDN for geothermal power plant investment.

Based on Table 2, the relationship between the combined TKDN and the component TKDN is as in equation 110 (PT. Biro Klasifikasi Indonesia, 2023).

$$D_T = \sum_{i=1}^n B_i D_i \quad (110)$$

Where  $D_T$  represents the composite TKDN value,  $B_i$  denotes the cost weight of component  $i$ ,  $D_i$  is the TKDN value of component  $i$ , and  $n$  is the number of cost components. From Equation (110), it can be seen that the composite TKDN value is a function of the component-level TKDN values. This implies that by setting the composite TKDN value as a constraint, the TKDN values of individual components may vary and thus serve as the decision variables.

Table 7. Optimization Scenarios

Scenario	Combined Domestic Components ( $D_T^S$ ) (%)
A	30,0
B	42,0
C	54,0
D	66,0
E	78,0
F	90,0

Based on Table 2, the reference composite TKDN value for geothermal power plant (GPP) investment costs is 28.9%. This value is set as the lower bound, while 100% is used as the upper bound. The complete set of composite TKDN scenarios employed in the optimization is presented in Table 7. These six scenarios may also be interpreted as a roadmap for gradually increasing the TKDN level of GPP investments.

## 2. Stage I Optimization

The economic impacts to be optimized include changes in output, value added (VA), household income, and employment. Optimizing only one type of economic impact does not necessarily yield optimal values for the other impacts. Therefore, in Stage I, optimization is carried out individually for each economic impact.

Changes in output are calculated using Equation (74). By substituting Equation (64) into Equation (74), the interim objective function for output changes is obtained, as expressed in Equation (111).

$$\max \rightarrow \Delta X_{T-JMB}^X = \sum_{j=1}^n O_j^{T-JMB} C_i^P D_i^{SX} \quad (111)$$

Where  $C_i^P$  represents the total investment cost of component  $i$ , and  $D_i^{SX}$  denotes the TKDN value of component  $i$  under the optimal output-change scenario.

The variables  $D_i^{SX}$  serve as the decision variables.

Using the same approach, by substituting Equation (64) into Equations (89), (99), and (109), the objective functions for changes in value added (VA), household income, and employment are obtained, as expressed in Equations (112) through (114).

$$\max \rightarrow \Delta V_{T-JMB}^V = \sum_{j=1}^n V_{mj}^{T-JMB} C_i^P D_i^{SV} \quad (112)$$

$$\max \rightarrow \Delta W_{T-JMB}^W = \sum_{j=1}^n W_{mj}^{T-JMB} C_i^P D_i^{SW} \quad (113)$$

$$\max \rightarrow \Delta L_{T-JMB}^L = \sum_{j=1}^n L_{mj}^{T-JMB} C_i^P D_i^{SL} \quad (114)$$

Where  $D_i^{SV}$  denotes the TKDN value of component  $i$  under the optimal value-added (VA) change scenario,  $D_i^{SW}$  represents the TKDN value of component  $i$  under the optimal household income change scenario, and  $D_i^{SL}$  refers to the TKDN value of component  $i$  under the optimal employment change scenario. The variables  $D_i^{SV}$ ,  $D_i^{SW}$ , and  $D_i^{SL}$  are treated as decision variables; however, the optimization is performed individually for each objective.

These individual optimizations are carried out using Microsoft Excel with the Solver add-in. The constraints applied to all four objective functions are identical, as described below.

$$D_i^R \leq D_i^{SX} \leq 100\% \quad (115)$$

$$D_i^R \leq D_i^{SV} \leq 100\% \quad (116)$$

$$D_i^R \leq D_i^{SW} \leq 100\% \quad (117)$$

$$D_i^R \leq D_i^{SL} \leq 100\% \quad (118)$$

$$D_T^{SX} = D_T^{SV} = D_T^{SW} = D_T^{SL} = D_T^S \quad (119)$$

### 3. Stage II Optimization

Based on the Stage I optimization, optimal values are obtained for changes in output, value added (VA), household income, and employment, where each impact is optimized individually.

Using the results of the Stage I optimization, Stage II optimization is then carried out by minimizing the deviations of these four economic impacts. The deviations are calculated using Equations 120 to 123, while the objective function is formulated as shown in Equation 124.

$$DEV_X = \frac{\Delta X_{T-JMB}^{X-max} - \sum_{j=1}^n O_j^{T-JMB} C_i^P D_i^S}{\Delta X_{T-JMB}^{X-max}} \times 100\% \quad (120)$$

$$DEV_V = \frac{\Delta V_{T-JMB}^{V-max} - \sum_{j=1}^n V_{mj}^{T-JMB} C_i^P D_i^S}{\Delta V_{T-JMB}^{V-max}} \times 100\% \quad (121)$$

$$DEV_W = \frac{\Delta W_{T-JMB}^{W-max} - \sum_{j=1}^n W_{mj}^{T-JMB} C_i^P D_i^S}{\Delta W_{T-JMB}^{W-max}} \times 100\% \quad (122)$$

$$DEV_L = \frac{\Delta L_{T-JMB}^{L-max} - \sum_{j=1}^n L_{mj}^{T-JMB} C_i^P D_i^S}{\Delta L_{T-JMB}^{L-max}} \times 100\% \quad (123)$$

$$\min \rightarrow DEV_T = DEV_X + DEV_V + DEV_W + DEV_L \quad (124)$$

Where  $\Delta X_{T-JMB}^{X-max}$  denotes the optimal change in output obtained from Stage I optimization, and similarly  $\Delta V_{T-JMB}^{V-max}$ ,  $\Delta W_{T-JMB}^{W-max}$ , dan  $\Delta L_{T-JMB}^{L-max}$ .  $DEV_X$  represents the deviation, or difference, between the optimal output change obtained in Stage I optimization and the output change resulting from Stage II optimization; similarly for  $DEV_V$ ,  $DEV_W$ , and  $DEV_L$ .

Meanwhile,  $DEV_T$  denotes the total deviation of the four economic impacts.  $DEV_T$  serves as the objective function in Stage II optimization.  $D_i^S$  represents the TKDN value of component iii under the optimal scenario and is treated as the decision variable.

The constraints for Stage II optimization are specified in Equations 125 and 126.

$$D_i^R \leq D_i^S \leq 100\% \quad (125)$$

$$D_T^S = 30; 42; 54; 66; 78; 90 \quad (126)$$

Up to this stage, the  $D_i^S$  value can be obtained for each scenario for each investment cost component, which results in the most optimal economic impact.

## Results

### Investment Costs, Concordance, and TKDN of Geothermal Power Plants (PLTP)

Using the PLTP investment targets presented in Table 1, investment costs were calculated according to Equation 2, with investment cost references taken from Table 2. The total investment cost required to add 35 PLTP units with a combined capacity of 1,915 MW amounts to IDR 114.7 trillion, averaging IDR 3.3 trillion per unit or IDR 59.9 billion per MW.

Figure 2 shows that more than half of the total investment cost is allocated to expenditures on the Balance of Plant (BoP), Steamfield Above Ground System (SAGS), and Engineering Services. These expenditures are predominantly incurred in the provinces of Central Java and West Java.

The results of the concordance of investment cost components are presented in Table 8. Based on this table, according to the 52 industrial sectors classification, the PLTP investment cost components are distributed across five industrial sectors, namely I-22, I-23, I-24, I-31, and I-48. Meanwhile, according to the 17 business field classification, the components are distributed across three business fields, namely C, F, and MN.

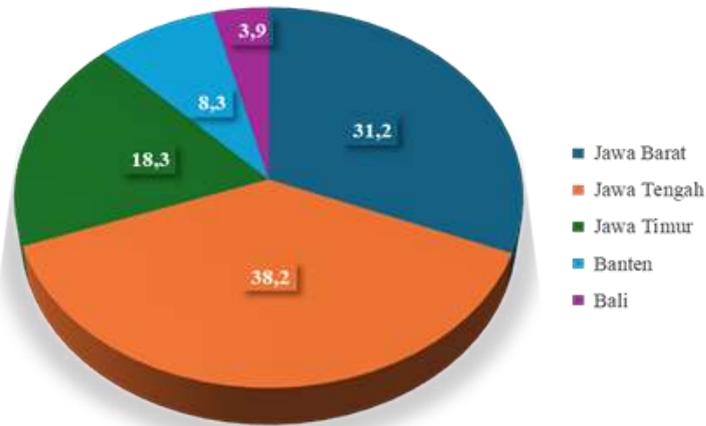


Figure 2. Total Investment Cost of the Java Madura Bali Regional Geothermal Power Plant by Component and Province (%)

Furthermore, with the TKDN value data for investment cost reference in Table 2, the comparison between the Domestic Component (KDN) and import values per Combined TKDN Scenario is shown in Figure 3. Based on this figure, the import value is getting smaller at each stage (scenario).

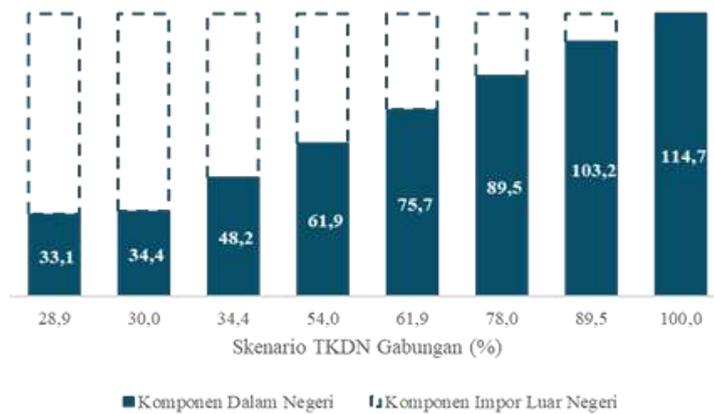


Figure 3. Comparison of Domestic Components (KDN) with Imports per Combined TKDN Scenario (Rp Trillion)

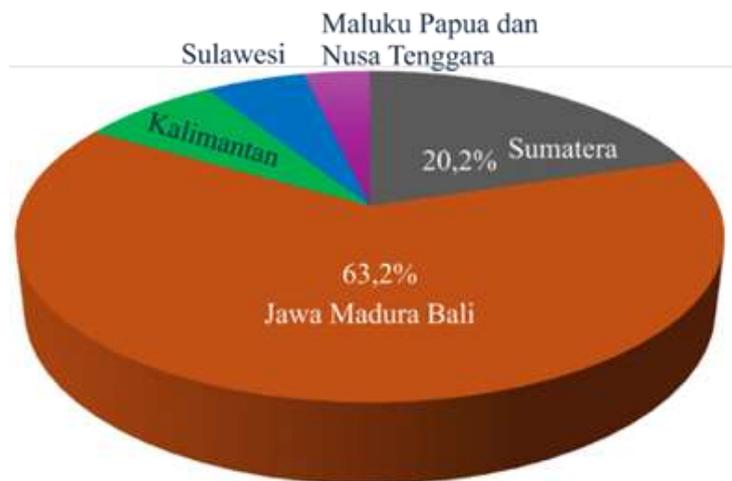


Figure 4. Percentage of Economic Output of 5 (Five) Regions

Table 8. Results of Concordance of Geothermal Power Plant Investment Costs with 52 Industrial Sectors and 17 Business Fields

1. Balance of Plant (BoP)		
KBLI 2015	24103	Iron and Steel Pipe and Pipe Fitting Industry
52 Industrial Sectors	I-22	Basic Metal Industry
17 Business Fields	C	Processing Industry
2. Steamfield Above Ground System (SAGS)		
KBLI 2015	25120	Metal Tank, Water Reservoir, and Container Industry
52 Industrial Sectors	I-23	Metal Products, Computer, Electronic, Optical, and Electrical Equipment Industry
17 Business Fields	C	Processing Industry
3. Generator		
KBLI 2015	25130	Steam Generator Industry, Not Boiler Industry
52 Industrial Sectors	I-23	Metal Products, Computers, Electronics, Optical, and Electrical Equipment Industry
17 Business Fields	C	Processing Industry
4. Electric and Instrumentation		
KBLI 2015	27120	Electrical Control and Distribution Equipment Industry
52 Industrial Sectors	I-23	Metal Products, Computers, Electronics, Optics, and Electrical Equipment Industry
17 Business Fields	C	Processing Industry
5. Steam Turbine		
KBLI 2015	28111	Steam Engine, Turbine, and Waterwheel Industry
52 Industrial Sectors	I-24	Machinery and Equipment Industry
17 Business Fields	C	Processing Industry
6. Civil and Steel Structure		
KBLI 2015	42213	Electrical Building Construction
52 Industrial Sectors	I-31	Construction
17 Business Fields	F	Construction
7. Jasa Engineering		
KBLI 2015	71102	YBDI's Engineering and Technical Consulting Activities
52 Industrial Sectors	I-48	Corporate Services
17 Business Fields	MN	Corporate Services

### The 2016 IRIO Table by Five Regions

Indonesia's total economic output in 2016 amounted to IDR 23.7 quadrillion. After aggregation into five regions, the largest shares of total output were recorded in the Java–Madura–Bali region (63.2%) and Sumatra (20.2%), as illustrated in Figure 4.

Figure 5 presents the allocation of output utilization across the five regions. At the national level, most output is absorbed by final demand. The largest share of final demand occurs in the Maluku–Papua and Nusa Tenggara regions, while the largest share of intermediate demand is observed in the Kalimantan region.

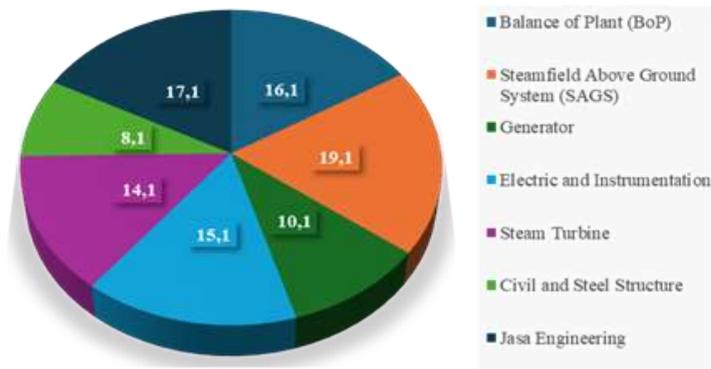


Figure 5. Percentage of Output Allocation by Region



Figure 6. Percentage of Input Allocation by Region

Nationally, to produce output, the majority of inputs are Gross Value Added (GVA) or Primary Inputs, the largest allocation in the Maluku, Papua and Nusa Tenggara regions (58.5%), as shown in Figure 6. Meanwhile, the largest percentage of intermediate inputs is in the Java, Madura, and Bali regions (47.5%).

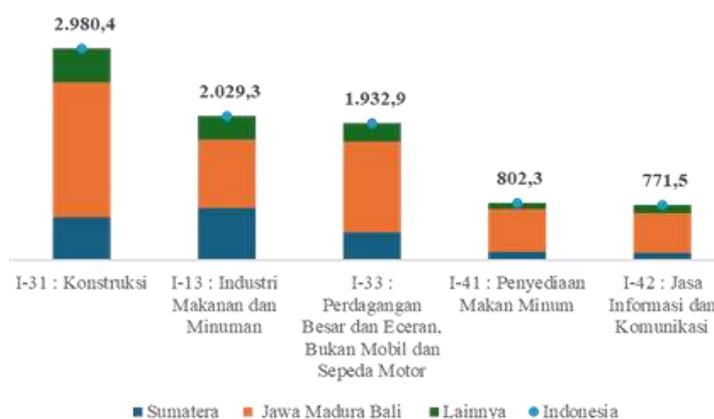


Figure 7. 5 (five) Largest Outputs based on Industrial Sector (Trillion Rupiah)

At the national level, the Construction sector (I-31) records the largest output, amounting to IDR 2.98 quadrillion, as shown in Figure 7. This is followed by the Food and Beverage Manufacturing sector (I-13), and then the Wholesale and Retail Trade, excluding Motor Vehicles and Motorcycles sector (I-33). Meanwhile, Figure 8 shows

that, by business field, Manufacturing (C) accounts for the largest share of output at 30.34%, followed by Construction (F) at 18.05%.

As discussed in Section 4.1, geothermal power plant (PLTP) investment costs are distributed across five industrial sectors or three business fields. Table 9 presents the total multipliers for these five sectors and three business fields in the Java–Madura–Bali region.



A : Pertanian, Kehutanan, dan Perikanan

C : Industri Pengolahan      F : Konstruksi

G : Perdagangan Besar dan Eceran; Reparasi Mobil dan Sepeda Motor

H : Transportasi dan Pergudangan

Figure 8. 5 (five) Largest Outputs based on Business Field (%)

Table 9. Multiplier Figures of Components of Geothermal Power Plant Investment Costs in the Java, Madura, and Bali Regions

Industrial Sector	$O_{Tj}^{JMB}$	$V_{Tmj}^{JMB}$	$W_{Tmj}^{JMB}$	Business Field	$L_{Tmj}^{JMB}$
I-22	1,74 5	0,8 36	0,2 28	C	3,569 1
I-23	1,72 3	0,7 89	0,3 12	F	4,116 <sup>1</sup>
I-24	1,92 0	0,8 47	0,3 08	MN	2,529 1
I-31	1,78 0	0,8 25	0,3 38		

I-48	1,54 3	0,8 92	0,4 02		
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1 thousand people per trillion rupiah

## Optimization

### 1. Optimal Economic Impacts

Stage I optimization applies Linear Programming to optimize economic impacts individually across four objective functions: changes in output, value added (VA), household income, and employment. The optimization is conducted based on the target or scenario of the combined domestic content (TKDN) of geothermal power plant (PLTP) investment. Overall results are presented in Table 10.

Based on Table 10, comparisons of optimization results across objective functions for each economic impact can be made row-wise. First, regarding output changes:

- In accordance with the logic of Linear Programming, the largest increase in output is achieved when the output change objective function is optimized individually.

Table 10. Results of Phase I Optimization Calculations (Individual Linear Programming)

Combined TKDN	Output	Gross Value Added	Household Income	Labor
	<i>Trillions of Rupiah</i>			<i>Thousands of People</i>
Optimization of $\Delta$ Output : $\max \rightarrow \Delta X_{T-JMB}^X$				
28,9	55,1	27,9	11,4	108,1
30,0	57,6	29,0	11,8	112,7
42,0	84,0	40,7	16,0	161,8
54,0	108,3	52,2	19,5	212,1
66,0	132,1	63,3	23,4	261,2
78,0	155,8	74,1	27,7	310,4
90,0	179,6	85,0	32,0	359,5
100,0	198,2	94,7	36,1	394,0
Optimization of $\Delta$ Gross Value Added: $\max \rightarrow \Delta V_{T-JMB}^V$				
28,9	55,1	27,9	11,4	108,1
30,0	57,1	29,1	11,9	111,4
42,0	81,7	41,0	16,6	155,4
54,0	107,0	52,6	20,3	204,5
66,0	131,0	63,9	24,0	254,8
78,0	154,7	74,8	28,3	303,9
90,0	178,4	85,6	32,6	353,1
100,0	198,2	94,7	36,1	394,0
Optimization of $\Delta$ Household Income: $\max \rightarrow \Delta W_{T-JMB}^W$				
28,9	55,1	27,9	11,4	108,1
30,0	57,1	29,1	11,9	111,4
42,0	80,1	40,5	16,7	156,6

54,0	103,8	51,4	21,0	205,7
66,0	127,5	62,3	25,3	254,8
78,0	152,4	73,5	29,6	303,9
90,0	178,2	85,1	33,5	353,1
100,0	198,2	94,7	36,1	394,0
Optimization of $\Delta$ Labor Force: $\max \rightarrow \Delta L_{T-JMB}^L$				
28,9	55,1	27,9	11,4	108,1
30,0	57,4	29,0	11,8	113,4
42,0	81,2	39,9	16,2	163,0
54,0	105,2	51,5	19,2	212,1
66,0	128,9	62,3	23,5	261,2
78,0	154,4	73,7	27,7	310,4
90,0	179,6	85,0	32,0	359,5
100,0	198,2	94,7	36,1	394,0

- b. Under individual optimization of the value-added (VA) objective function, output changes decrease by an average of 1.25 trillion rupiah per combined TKDN scenario. The largest decline occurs at a combined TKDN level of 42%, with a reduction of 2.3 trillion rupiah.
- c. Under individual optimization of the household income objective function, output changes decrease by an average of 3.08 trillion rupiah per combined TKDN scenario. The largest decline is observed at the combined TKDN level of 66%, amounting to 4.63 trillion rupiah.
- d. Under individual optimization of the employment objective function, output changes decrease by an average of 1.80 trillion rupiah per combined TKDN scenario. The largest decline also occurs at the combined TKDN level of 66%, with a reduction of 3.19 trillion rupiah.

Second, the impact of changes in NTB:

- a. Changes in value added reach their highest levels when the value-added objective function is optimized individually.
- b. Under individual optimization of the output change objective function, value-added changes decrease by an average of 0.43 trillion rupiah per combined TKDN scenario. The largest reductions occur at combined TKDN levels of 66%, 78%, and 90%, each declining by 0.63 trillion rupiah.
- c. Under individual optimization of the household income change objective function, value-added changes decrease by an average of 0.85 trillion rupiah per combined TKDN scenario. The largest decline occurs at the combined TKDN level of 66%, amounting to 1.64 trillion rupiah.
- d. Under individual optimization of the employment change objective function, value-added changes decrease by an average of 0.92 trillion rupiah per combined TKDN scenario. The largest decline also occurs at the combined TKDN level of 66%, with a reduction of 1.57 trillion rupiah.

Third, the impact on changes in household income:

- a. Changes in household income reach their maximum values when the household income objective function is optimized individually.
- b. Under individual optimization of the output change objective function, household income changes decrease by an average of 1.25 trillion rupiah per

combined TKDN scenario. The largest reduction occurs at the combined TKDN level of 66%, amounting to 1.86 trillion rupiah.

- c. Under individual optimization of the value-added change objective function, household income changes decrease by an average of 0.72 trillion rupiah per combined TKDN scenario. The largest decline occurs at the combined TKDN level of 66%, totaling 1.31 trillion rupiah.
- d. Under individual optimization of the employment change objective function, household income changes decrease by an average of 1.26 trillion rupiah per combined TKDN scenario. The largest reduction occurs at the combined TKDN level of 78%, with a decrease of 1.81 trillion rupiah.

Fourth, the impact on changes in employment:

- a. Changes in employment reach their highest levels when the employment objective function is optimized individually.
- b. Under individual optimization of the output change objective function, employment changes decrease by an average of 314 workers per combined TKDN scenario. The largest decline occurs at the combined TKDN level of 54%, with a reduction of 1,174 workers.
- c. Under individual optimization of the value-added change objective function, employment changes decrease by an average of 5,013 workers per combined TKDN scenario. The largest reductions occur at combined TKDN levels of 54% and 66%, each declining by 7,594 workers.
- d. Under individual optimization of the household income change objective function, employment changes decrease by an average of 4,622 workers per combined TKDN scenario. The largest declines occur at combined TKDN levels of 54%, 66%, 78%, and 90%, each decreasing by 6,420 workers.

The four findings above demonstrate that each objective function has its own preference or goal and that these objectives are not always aligned or linear. Changes in output experience the largest average decline under optimization of the household income objective function. Changes in value added show the largest average decline under optimization of the employment objective function. Changes in household income experience the largest average decline under optimization of the employment objective function. Meanwhile, changes in employment show the largest average decline under optimization of the value-added objective function.

For this reason, Stage II optimization is required as a form of “negotiation” to achieve a simultaneous and balanced optimization of all four economic impact indicators. The results of the Stage II optimization are presented in Table 11.

Table 11. Results of Phase II Optimization Calculations

Combined TKDN	Output	Gross Value Added	Household Income	Labor
	<i>Trillions of Rupiah</i>			<i>Thousands of People</i>
28,9	55,1	27,9	11,4	108,1
30,0	57,4	29,0	11,8	113,4
42,0	83,7	40,6	16,1	163,0
54,0	108,1	51,7	20,4	212,1
66,0	131,8	62,6	24,7	261,2
78,0	155,5	73,4	29,0	310,4

90,0	178,2	85,1	33,5	353,1
100,0	198,2	94,7	36,1	394,0

Table 11 illustrates how each economic impact indicator declines relative to the Stage I optimization results as a form of “negotiation” to achieve simultaneous optimal outcomes. Output changes decrease by an average of IDR 0.45 trillion per combined TKDN scenario. Changes in gross value added (GVA) also decline, with an average reduction of IDR 0.75 trillion. Household income changes decrease by an average of IDR 0.42 trillion, while employment declines by an average of 1,070 jobs per combined TKDN scenario.

## 2. Distribution of Economic Impacts

The economic impacts discussed in the previous section represent total or national impacts. This subsection provides a more detailed examination of the regional distribution of economic impacts. By applying the equations presented in Section 3.4, the spatial distribution of economic impacts across regions can be identified.

Based on the Stage II optimization results shown in Table 11, the distribution of output changes is illustrated in Figure 9. The figure indicates that the majority of output changes occur within the Java–Madura–Bali region itself, accounting for an average of 95%. Interregional output changes account for approximately 5% on average. Of these interregional effects, the majority—around 71%—flow to the Sumatra and Maluku–Papua–Nusa Tenggara regions, while the remaining 29% are distributed across Kalimantan and Sulawesi.

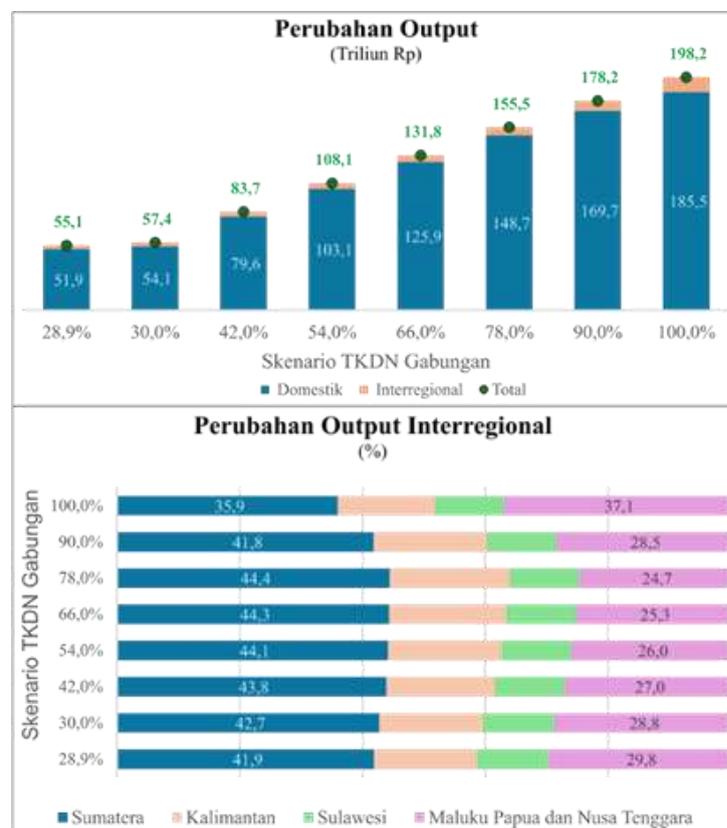


Figure 9. Distribution of Output Changes Due to Geothermal Power Plant Investment in the Java, Madura, and Bali Regions

The distribution of changes in gross value added (GVA) is illustrated in Figure 10. As shown in the figure, the majority of GVA changes occur within the Java–Madura–Bali region itself, averaging 93%, while the remainder represents interregional GVA changes. Of the interregional effects, the majority—approximately 72% on average—flow to the Sumatra and Maluku–Papua–Nusa Tenggara regions, with the remaining 28% occurring in Kalimantan and Sulawesi.

Next, the distribution of changes in household income is presented in Figure 11. The figure indicates that most household income changes take place within the Java–Madura–Bali region, averaging 95%, while the remaining share flows to other regions as interregional impacts. Of these interregional household income effects, around 72% on average accrue to the Sumatra and Maluku–Papua–Nusa Tenggara regions, with the remaining 28% experienced by Kalimantan and Sulawesi.

Finally, the distribution of changes in employment is shown in Figure 12. According to the figure, the majority of employment changes occur within the Java–Madura–Bali region itself, averaging 96%, while the remaining share represents interregional impacts. Of the interregional employment effects, approximately 76% on average flow to the Sumatra and Kalimantan regions, with the remaining 24% occurring in Maluku–Papua–Nusa Tenggara and Sulawesi.

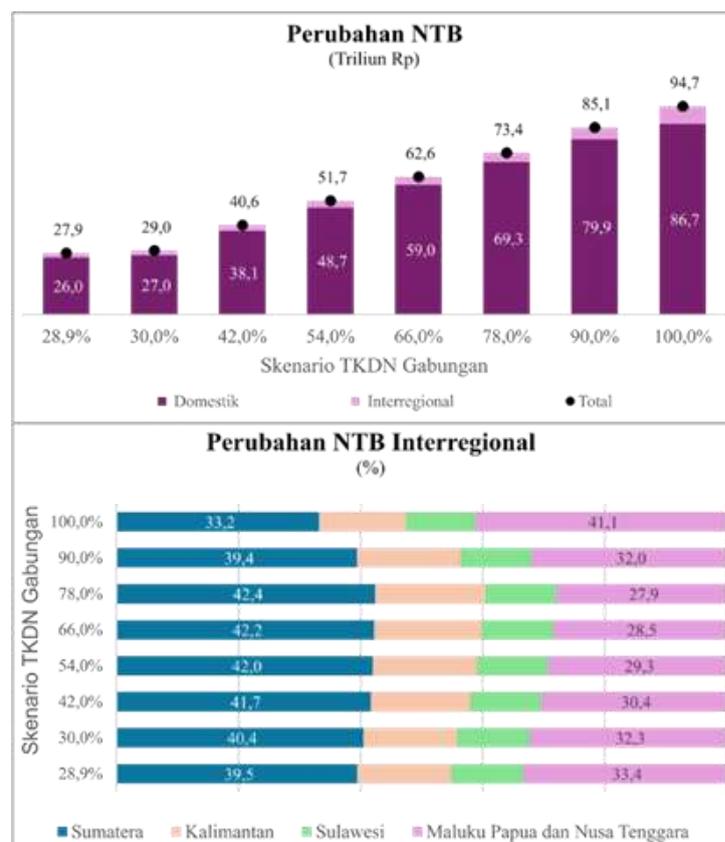


Figure 10. Distribution of Changes in NTB Due to Geothermal Power Plant Investment in the Java, Madura, and Bali Regions

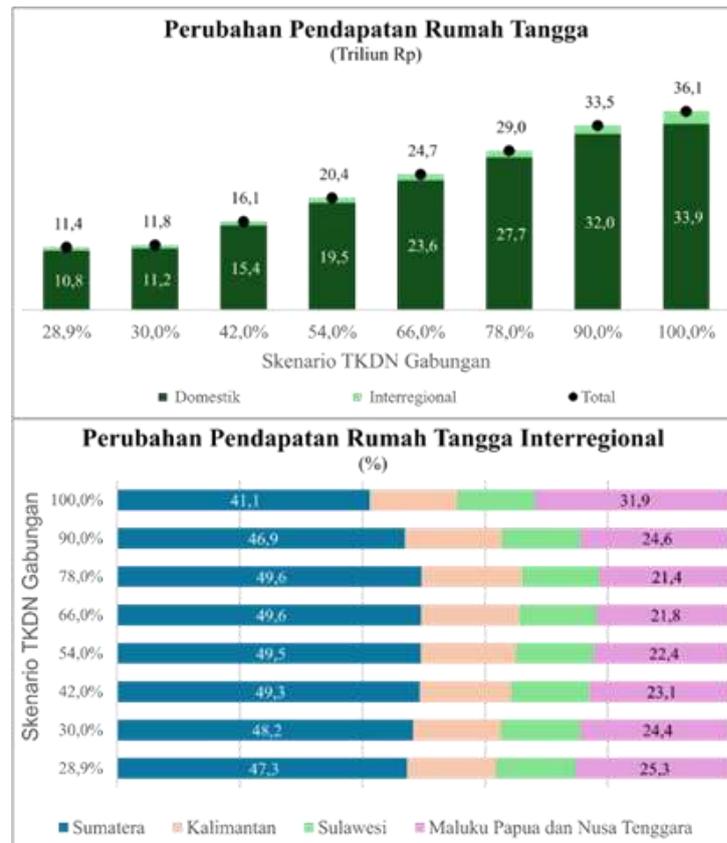


Figure 11. Distribution of Changes in Household Income due to Geothermal Power Plant Investment in the Java, Madura, and Bali regions

### 3. Optimal TKDN Targets for Geothermal Power Plant Investment Components

Table 11 in the previous section presents the optimal economic impacts of geothermal power plant (GPP) investment in the Java–Madura–Bali region for each combined TKDN scenario. These optimal economic outcomes subsequently generate a “roadmap” or target trajectory for increasing the TKDN of individual investment cost components, as illustrated in Figure 13.

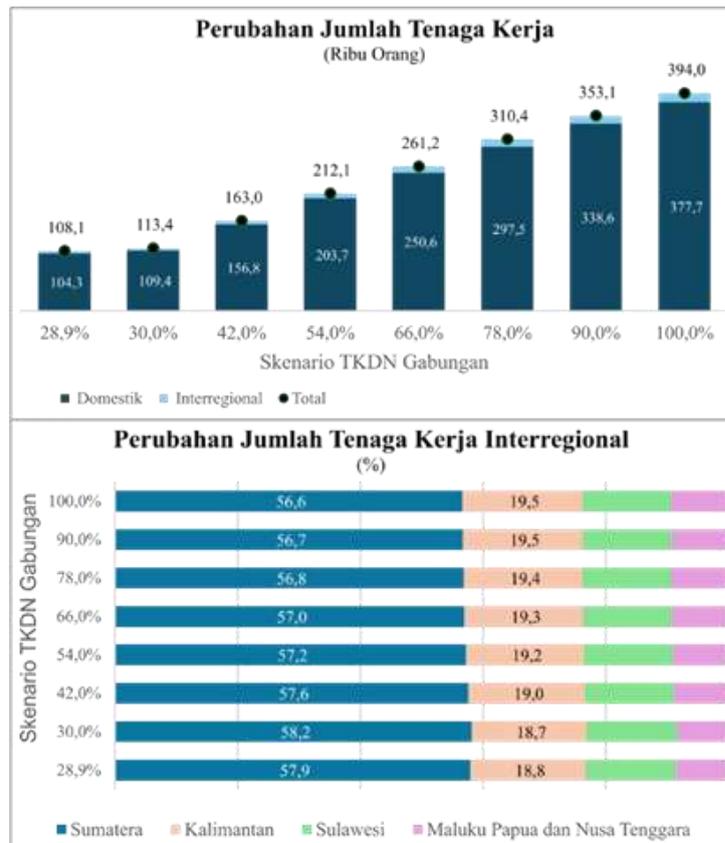


Figure 12. Distribution of Changes in the Number of Workers Due to Geothermal Power Plant Investment in the Java, Madura, and Bali Regions

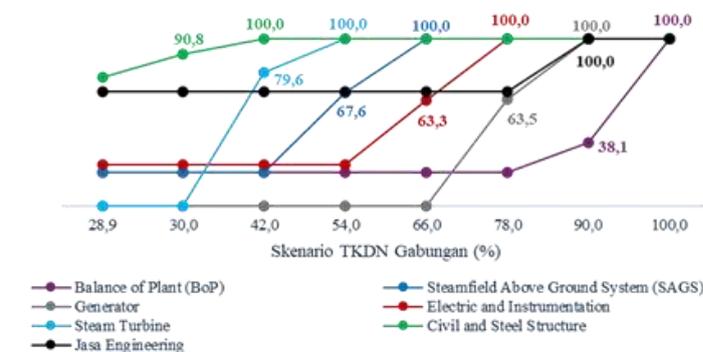


Figure 13. Target for Increasing TKDN Components of Geothermal Power Plant Investment Costs Based on the Combined TKDN Scenario (%)

Based on Figure 13, several key findings can be identified:

- First stage: When the combined TKDN target increases from 28.9% to 30%, only the *Civil and Steel Structures* component shows an increase in TKDN, rising from 77% to 90.8%.
- Second stage: With the combined TKDN target increasing from 30% to 42%, the TKDN of *Civil and Steel Structures* continues to rise from 90.8% to 100%. At the same time, the *Steam Turbine* component experiences a very significant increase in TKDN, from 0% to 79.6%.
- Third stage: When the combined TKDN target increases from 42% to 54%, the TKDN of the *Steam Turbine* component continues to rise from 79.6% to 100%.

Meanwhile, the *Steamfield Above Ground System (SAGS)* component shows a substantial increase in TKDN, from 20% to 67.6%.

- d. Fourth stage: With the combined TKDN target increasing from 54% to 66%, the TKDN of the *SAGS* component continues to rise until it reaches 100%. In this stage, the *Electrical and Instrumentation* component experiences a significant increase in TKDN, from 20% to 63.3%.
- e. Fifth stage: When the combined TKDN target increases from 66% to 78%, the TKDN of the *Electrical and Instrumentation* component reaches 100%. At this stage, the *Generator* component shows a significant increase in TKDN, from 0% to 63.5%.
- f. Sixth stage: With the combined TKDN target increasing from 78% to 90%, the TKDN of both the *Generator* and *Engineering Services* components reaches 100%. Meanwhile, the TKDN of the *Balance of Plant (BoP)* component increases from 20% to 38.1%.

These targets for increasing the TKDN of geothermal power plant investment components are based on investments in the Java–Madura–Bali region and are derived through optimization of economic impacts using the Linear Programming method. As a result, the outcomes may appear somewhat utopian or overly optimistic. This is because the logic of Linear Programming is to maximize the objective function— in this case, economic impacts. Components with large cost shares and strong multiplier effects are therefore strongly encouraged by the model to achieve substantial increases in TKDN in order to maximize economic impacts.

It should be noted that the Linear Programming model in this study does not account for technical or practical challenges, such as the feasibility of achieving the targeted TKDN levels for each component. Instead, Linear Programming serves as a decision-support tool to identify optimal TKDN targets for geothermal power plant investment components in order to maximize economic impacts.

## Conclusion

This study proposes an integrated Interregional Input–Output (IRIO) and Linear Programming (LP) approach to optimize the economic impacts of increasing the combined Domestic Content Level (TKDN) in geothermal power plant (PLTP) investments in the Java–Madura–Bali region. This optimization framework is essential to ensure that government programs and policy interventions aimed at increasing TKDN in PLTP investments are more focused, well-targeted, and capable of generating optimal economic impacts. In particular, the approach helps identify which of the seven PLTP investment cost components should be prioritized.

Based on the combined TKDN target scenarios, the results indicate that the priority order for increasing TKDN in PLTP investment components is as follows: Civil and Steel Structures, Steam Turbine, Steamfield Above Ground System (SAGS), Electrical and Instrumentation, Generator, and Balance of Plant (BoP). This prioritization yields optimal economic impacts at each stage of TKDN enhancement.

Increasing TKDN in PLTP investments may also contribute to reducing overall investment costs. As the share of domestically produced components rises, production costs are likely to decrease, thereby lowering component prices and, ultimately, total investment costs.

Not all countries possess geothermal energy potential; consequently, the development and research of geothermal power technologies remain relatively limited.

Unlike solar or wind power technologies, it is unrealistic to expect broad global participation in geothermal technology development. Therefore, pursuing self-reliance through the development of domestic supporting industries for geothermal power plants represents a challenging yet necessary path, reflecting Indonesia's responsibility to utilize its abundant geothermal resources. Collaboration with other geothermal-rich countries is essential to accelerate technological advancement and innovation.

Future research may further explore and elaborate on policy instruments and supporting mechanisms required to enhance TKDN for each PLTP investment cost component. Methodological extensions could also incorporate multi-objective linear programming to simultaneously optimize multiple economic indicators.

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