Towards an eco-industrial development in West Papua economy

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Abstract. West Papua province holds a crucial role to ensure the NDC target could be achieved in a measurable and timely manner. Despite its rich possession of pristine biodiversity, manufacture industry contributes 3% of the total provincial income. This study aims to predict the GRDP if West Papua incorporates Eco-Industrial Development (EID) to mitigate emissions from the industrial sector and its shares to the local community's economy and the global economy. System dynamic modelling was employed to simulate and project the scenarios. The results show that the GRDP projection under the BAU scenario will rise from about 1,200 billion IDR in 2010 to 2,500 billion IDR in 2030, in parallel with the gradual increase of GHGs emission to 72,000 tonCO2e. The intervention scenario shows that the emissions will reach 57,000 tonCO2e and the economic contraction to 2,000 billion IDR by 2030. Considering the intermediate input, the added benefit for local communities in 2030 could fall from 840 billion IDR to 670 billion IDR in the intervention scenario. The contribution to the outer region's economy could decrease from 230 to 180 billion IDR. Besides the benefit of EID to reduce emissions, the government should also consider the impact of economic contraction.

1. Introduction

Eco-Industrial Development (EID) refers to an environmentally friendly business framework by reducing carbon footprint and environmental damage [1]. The concept promotes mutually beneficial linkages among industrial process, environmental system, material, and local people to design the ideal industrial scheme. The Government of Indonesia in 2016 ratified Paris Agreement and issued Nationally Determined Contribution (NDC) document that highlights commitment to reduce GHGs emission by 29% to 41% subject to international assistance. This pledge encourages Indonesia to transition from brown to a green economy by creating socio-economic opportunities on the low-carbon agenda and increasing adaptability from the adverse effect of climate change [2].

The sub-national contribution has a pivotal role in achieving sustainable development and NDC target. West Papua Province as Indonesia's last forest frontier holds an imperative role to achieve low carbon development goals. Having a forest cover area of 90% out of a total it does not contribute significantly towards the regional income. The regional income from the land-use sector contributes about 6,050 billion IDR or 10% in 2018. In the last five years, industry sector, including the Coal

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Industry, as well as, Oil and Gas Refining Industry, has contributed significantly to the regional income after mining activities, at the average rate of 26.96% and boost economic growth to 5.04% in 2019 [3]. Also, it stimulates the growth of other sectors, including increasing the work participation rate by 68.27% [4].

Therefore, restructuring the economic framework is required to optimize the availability of local resources in West Papua fully. With its geographical conditions and biodiversity, the driving force for the industrial sector should involve sustainable aspect within the business process. The transformation can be in the form of technology transfer and sustainable use of natural resources to ensure that the regional development could balance sustainable economic growth and social welfare of local communities.

Under the industrial process, it is necessary to calculate the value of input and output to measure the level of productivity in the production process [5]. Among these production factors, intermediate input stands as the value of using goods and services in the production process [6]. The lack of local production factors increases the flows of external goods and services, which indirectly, influencing the intermediate input factor. Beyond accelerating the flow of factor production, management, and technology, it also stimulates the mobility of labour and capital [7].

Research from Labiba & Pradoto [8] shows that the intensity of CO_2 emissions from industry-related operations has the potential to increase through 2031 [8] steadily. A large number of industrial products such as chemicals, cement products, petroleum, processed food products, beverage goods, metals and pharmaceuticals generate emissions. Jia *et al.* (2017) emphasize that an integrated system-based approach between human and nature would establish a sustainable industrial process [9].

The Ministry of Environment and Forestry (2017) reported that emissions of GHG were 1.5 $GtonCO_2e$ in 2016 – had increased by 2.9% per annum since 2000 [10]. This regional contribution from industry sector was 8.7% out of total national emissions reduction target of NDC. The increase of 18% of GHG emissions during 2012-2016 generated from the power plant, manufacturing, and transport sectors.

Developing productive production to boost GRDP can encourage economic growth. However, industrial activities in West Papua shows significant dependence on external resources such as skilled labour and imported products, including raw materials. Therefore, industrial transformation is needed to reduce reliance on imports of goods and services.

Conrad & Kulkarni [11] introduces the "Big Push" concept, stating that policy development must be pursued through changes in fiscal and monetary policies that affect economic growth [11]. In this regard, it is essential to optimize industry sector to design activities that could encourage other sectors to develop (forward linkage) and activities that require other sectors to run their activities (backward linkage), that are shaped by stages to boost the transformational economy which eventually, will increase economic competitiveness.

This study aims to predict the GRDP obtained if West Papua incorporates Eco-Industrial Development (EID) to mitigate emissions from the industrial sector and its shares to the local community's economy and the global economy. Two key research questions include; (1) How much the GRDP and the potential contribution of GHG emissions reduction in West Papua under the BAU scenario and EID scenario? and (2) How is the impact of the two scenarios to the added benefit for local communities and the contribution for the global economy through the integration of West Papua economy with global economy outside West Papua? Also, this study excludes the Coal Industry and the Oil and Gas Refining Industry from the industrial sector to avoid double counting of GHGs emissions because the emissions from these two industrial sectors are calculating in the energy sector.

2. Method
In general, there are three functions of system dynamics models, comprises of 1) the design of system structure to decide characteristics of the system; 2) the design of structural properties to recognize the behaviour of the system, and 3) the redesign of a model with newly defined characteristics [12]. In this research, the model was created to represent the socio-economic and environmental circumstances in

West Papua province. The characteristics assessed by indicators of regional income and expenditure, intermediate inputs, and emissions level. The model is to measure the value-added of the industrial sector if the level of emissions at a certain level. The modelling stages include conceptualization, modelling, simulation, and validation.

2.1. Model description

The system dynamics model is used to interlink variables with other intertwined aspects, including the value-added industrial sector, industrial resources, emissions, and other elements of production factors. The simulation data for this model was collected from 2010-2018 of Central Bureau of Statistics data and findings from other studies. There are three main elements in the system dynamics model, namely stock variable, flow variable, and additional variable. The stock variable is often referred to as the level variable, describing the leading associations of the system. The flow variable is indicating by the valve, created by a combination of investment-related features in the industrial sector. It also shows the relationship between each variable in the graph. The model's interaction is determined by the feedback loop, represented by an arrow in the diagram. The interaction is negative (-) if the decrease in one element causes a decrease in another element, and vice versa, the positive sign (+) indicates the opposite impact towards other elements.

The design and development of stock-flow diagrams carried out using the formulation and dimensional testing of the model structure. Formulations are made under the basis of historical data and knowledge in differential equations to explain problems. Dimension testing is performed by checking the unit of measurement for model variables that include degree, rate, auxiliary, and constant. If the formulation and dimensional testing have been completed, the simulation can be carried out within the determined period. To better recognize the model's behaviour, several scenarios are tested in the simulation model. The scenario is expected to demonstrate the ability of capital to boost economic benefit from the industry sector.

2.2. Causal loop diagram

A causal diagram that helps to visualize the critical elements in building model is known as the Causal loop diagram (CLD). It illustrates the economic growth of the industrial sector under the BAU scenario compare to intervention scenario of EID. The model strives to analyze the trend of economic growth from the industry sector to identify better the causal relationships that shape a low carbon economic model in the West Papua province.

Figure 1 shows the CLDs between BAU scenario and EID scenario (intervention). The EID scenario follows the target under NDC framework to reduce GHG emissions 29% and 41%. The BAU scenario shows the potential investment (represented by 'Industrial Sector Capital') to produce value-added income for the industrial sector (represented by 'GRDP of Industrial Sector') and GHGs emissions (represented by GHGs of Industrial Sector). The value-added will stimulate investment in the manufacturing industry and the social welfare of local communities. There is a reinforcing loop (R1) perpetuating the increasing of GHGs emission from the Industrial Sector. On the other side, the EID scenario shows that there are attempts to reduce GHGs emissions following the commitment of NDC, thereby affecting the investment in the industrial sector. It creates a second loop that balances the reinforcing loop (R1) and helps to control the GHGs emission from the Industrial Sector, as well as, implementing eco-industrial development concept in West Papua.
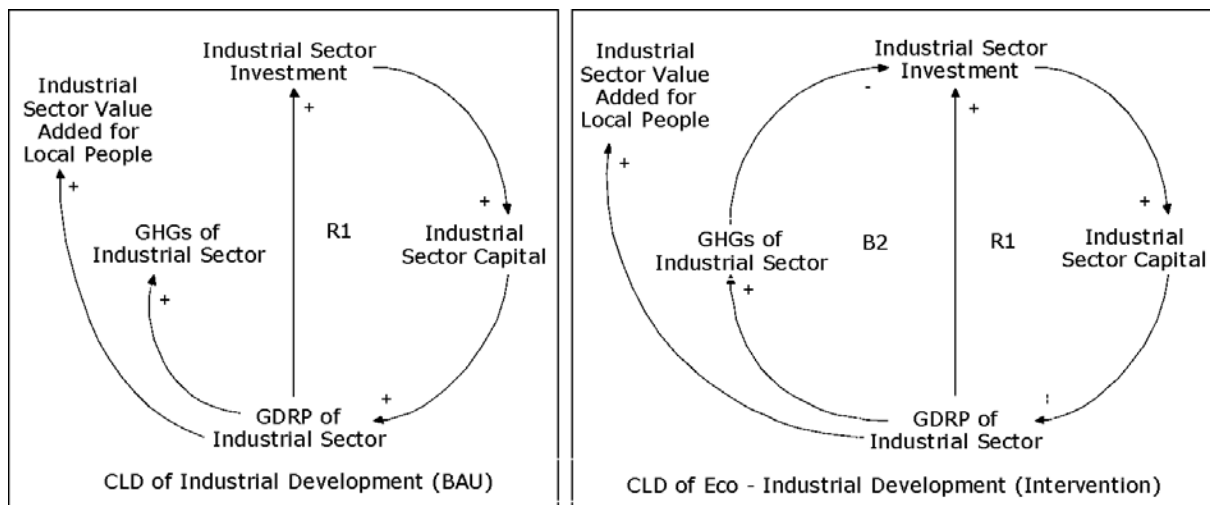
Figure 1. Causal loop diagram of the industrial sector.

The growth of GRDP from industry sector and investment as two critical factors in the CLD can be used to describe the underlying logical relationships and system behaviour in the decision-making process over time. Under these two loops, some differences affect the Capital Output Ratio (COR) or investment feasibility level of industry sector, namely industrial GRDP production factor.

2.3. Stock flow diagram

Stock Flow Diagram (SFD) is an advanced stage in the development cycle of system dynamic modelling. SFD is a CLD derivative that represents the main predictor in CLD. In SFD, additional necessary variables for explicit modelling can be added as essential indicators to influence the flow of the model (Figure 2).
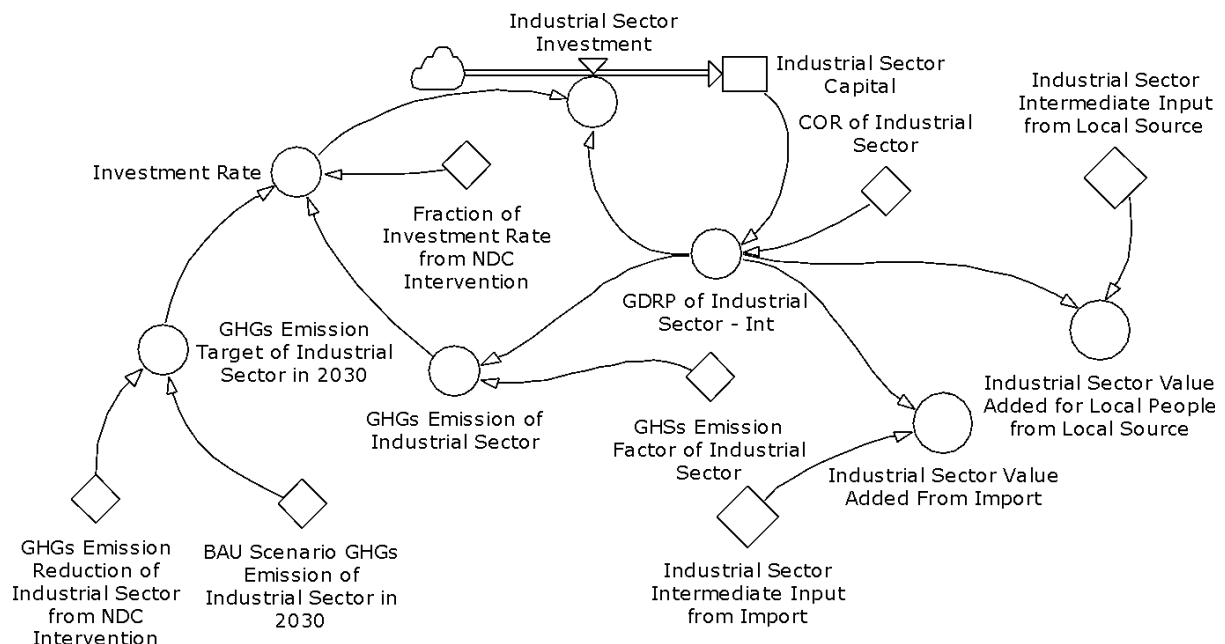

Figure 2. Stock and flow diagram of eco-industrial development.

The model simplifies the dynamics of the real world; hence limitations exist under the model. COR element provides a value-added to the industrial sector, while GHG emissions element influence the investment scheme. The model emphasizes an emissions reduction target to meet with the national target under the NDC framework. The figure 2 shows that the investment used to build GRDP lies in the components that could generate emissions fractions. Assumptions are designed to address the limitations of the model. The model's variables and assumptions cover in Table 1.

Table 1. Variables and assumptions used.

No	Variable	Value / Formula	Unit	Data Source
1	Industrial Sector Capital	5,989.844	Billion Rupiah	Adjusted Variable Data
2	COR of Industrial Sector	4.98		Secondary data
3	GHSs Emission Factor of Industrial Sector	29.41	$tonCO_2e$	Secondary data
4	The fraction of Investment Rate from NDC Intervention	37 (in NDC 29%) 38 (in NDC 41%)	%	Adjusted Variable Data
5	GHGs Emission Reduction of Industrial Sector form NDC Intervention	3.95 (in NDC 29%) 4.67 (in NDC 41%)	%	Secondary data
6	BAU Scenario GHGs Emission of the Industrial Sector in 2030	71,959.543	$tonCO_2e$	BAU Scenario Simulation Result
7	Industrial Sector Intermediate Input from Import	9.5	%	Secondary data
8	Industrial Sector Intermediate Input from Local Source	34.4	%	Secondary data
9	Investment Rate	in BAU: 18 in NDC 29% & 41%: (1 - ('GHGs Emission of Industrial Sector' / 'GHGs Emission Target of Industrial Sector in 2030')) * 'Fraction of Investment Rate from NDC Intervention'	%	
10	Industrial Sector Investment	('GRDP of Industrial Sector' * 'Investment Rate') / 1<<year>>	Billion Rupiah/year	
11	GRDP of Industrial Sector	'Industrial Sector Capital'/'COR of Industrial Sector'	$tonCO_2e$	
12	GHGs Emission of Industrial Sector	'GRDP of Industrial Sector' * 'GHSs Emission Factor of Industrial Sector'	$tonCO_2e$	
13	GHGs Emission Target of the Industrial Sector in 2030	'BAU Scenario GHGs Emission of the Industrial Sector in 2030' * (100<<%>> - 'GHGs Emission Reduction of Industrial	$tonCO_2e$	

| 14 | Industrial Sector Value Added for Local People from Local Source | Sector from NDC Intervention') 'Industrial Sector Intermediate Input from Local Source'*'GRDP of Industrial Sector' | Billion Rupiah |
| 15 | Industrial Sector Value Added from Import | 'Industrial Sector Intermediate Input from Import' * 'GRDP of Industrial Sector' | Billion Rupiah |

2.4. Simulation and validation of the model

At this point, the model is successively validating through the data and structural validation by seeing to the result. System structure validation involves the validity of model structure logic and the validity model structure with the real-world system. Validation of the structural model refers to the constraints, variables, and assumptions of the system. Validation is affected by comparing the performance of the model with the simulation results on the available data. The validation method uses the formula of AME (Absolute Means Error).

$$AME = [Si - Ai] / Ai \ x \ 100\% \tag{1}$$

where: A = real value; S = simulation value; N = observation time interval.

The AME value uses 30% limit value; this value is correlated with several variables which cannot be managed.

In this step, the time-series data of the GRDP of Industrial Sector throughout 2010-2018 are used as a reference. The reference excludes the data form the Coal Industry and the Oil and Gas Refining Industry because the emissions from these two industrial sectors are calculated in the energy sector. The validation result of the industrial GRDP shows that the AME value is 0.44% below the 30% limit value, which means the model of simulation is valid (Table 2).

**Table 2.** Validation from GRDP of Industrial Sector (Billion IDR).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	Ave.	AME
Ref.*	1,203	1,236	1,293	1,357	1,429	1,457	1,482	1,539	1,588	1,398	0.44%
Sim.	1,203	1,246	1,291	1,338	1,386	1,436	1,488	1,542	1,598	1,392	

*) Data source: West Papua Central Statistics Agency

3. Results and discussion

Figure 3 is a simulation of West Papua Province Industrial GRDP. Under the BAU scenario, industrial GRDP projected to rise from 1,200 billion (2010) to over 2,500 billion (2030). In comparison, the emissions will steadily rise to more than 60,000 $tonCO_2e$ by 2030. This condition allows the accumulation of CO_2 to be reasonably high.
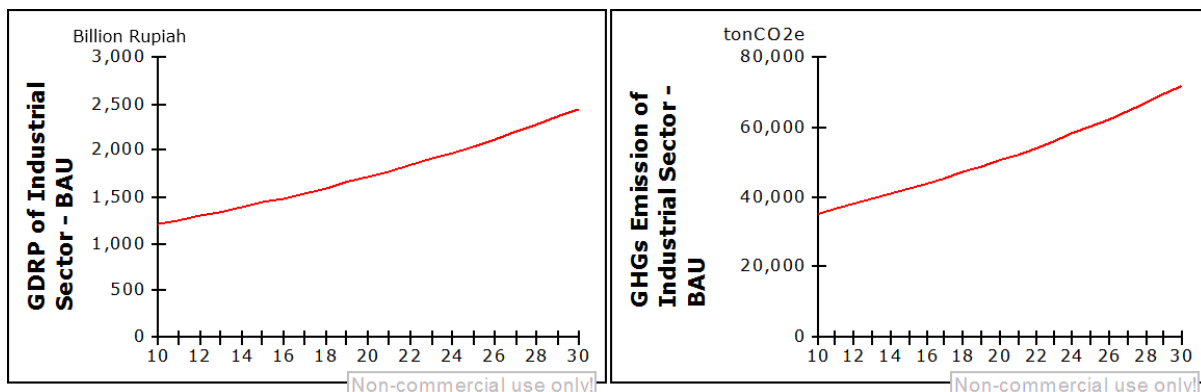
Figure 3. Simulation results of Business-As-Usual (BAU) Scenario.

3.1. Industrial sector GRDP and GHGs emission in West Papua

Figure 4 shows three simulation scenarios of GRDP in West Papua province. The BAU scenario shows the trajectory of regional income with the assumption of no external intervention or climate mitigation activities for regional development in the industry sector. The second and third scenarios are the Eco-Industrial Development scenario (EID scenario) with the assumption if EID activities are being conducted under the framework of NDC target of 29% and 41% of GHGs emissions reduction by 2030.

Based on the conditions set out in the BAU scenario, the economy will rise along with the provincial emissions. New strategies can be implemented to limit the increase in emissions. Figure 4 shows West Papua GRDP of 29% and 41% NDC target in 2030 for reducing GHGs emissions toward its base year of 2010 (EID scenario).
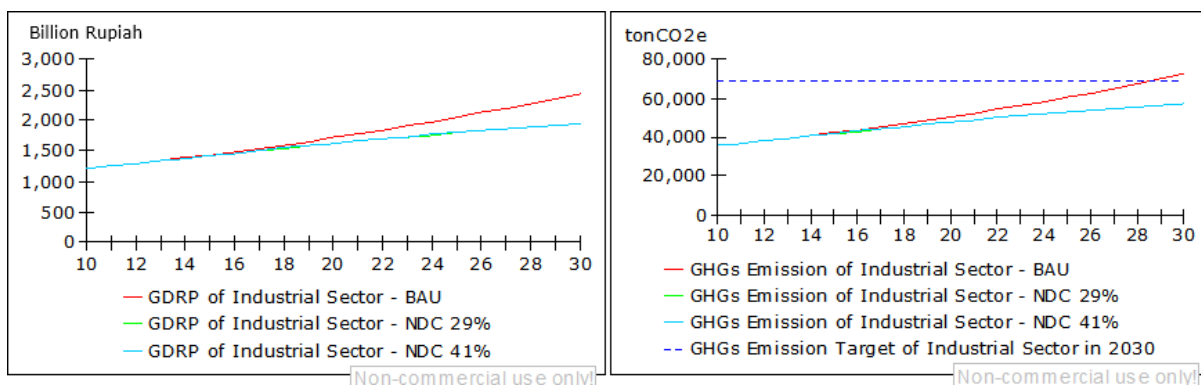
Figure 4. Simulation results of industrial sector GRDP and GHGs emission.

Figure 4 (left) shows that the GRDP under BAU scenario, along with the intervention scenario of NDC target will increase steadily through 2030 along with the difference in regional income of around 500 billion IDR by 2030. In Figure 4 (right), the emissions produced from all scenarios also will rise within two decades. Hidayatno *et al.* (2018) explain this rising phenomenon as the impact of the fuel combustion activities in the industrial sector [13]. Even though all scenarios show the growth trend in the GHGs emission, the increase in emissions of BAU scenario has the potential to thwart the commitment to the NDC target since it will exceed emissions threshold in 2030.

Contrary, the EID scenario of NDC 29% and 41% can reduce emissions about 14,700 $tonCO_2e$ in 2030 or below the emissions threshold in 2030. The emissions produced by the NDC 29% and 41% scenario is about 57,050 $tonCO_2e$ and 57,180 $tonCO_2e$ in 2030. The difference between each intervention is small because of the emissions reduction target for the industrial sector in 2030 is

3.95% for NDC 29% and 4.67% for NDC 41%. However, the climate mitigation action under EID scenario industrial sector will correct the industrial sector GRDP in 2030 to about 2,000 billion IDR.

The 2020 Carbon Economy Value Instrument Strategy agreed to reduce emissions from the manufacture and national transport sectors by 11%. The document also highlights the goal to reduce GHGs emissions in West Papua province at 15% by 2030 by integrating low-carbon policies into the provincial development plan. Based on the simulation, it is essential to consider the contraction of GRDP in the industrial sector into the provincial mitigation plan. Thus, the climate change mitigation strategy in West Papua will also go hand in hand with the attempt to prosper the local economy.

3.2. The integration of West Papua regional economic development with the global region
Figure 5 simulations show the relationships between the regional income of West Papua compare to the global region under BAU and EID scenario. The simulation results use intermediate inputs with different proportions from the local and imported inputs. These inputs produce industrial sector output which benefits West not only West Papua but other provinces and the global economy as well. It shows that the intermediate input import has increased the GRDP of the industry in West Papua under both BAU and EID scenario. The acquisition of value-added in the GRDP of the industrial sector in West Papua has accounted for at least 34.4% of the local intermediary inputs, whereby 9.5% share of intermediate input imports is GRDP. The remaining 56.1% is the contribution of other factors of production, including labour production factors (the indicator is not visualizing in the model). Thus, the value-added gained by local people for the local inputs in the industry sector is comparatively higher than the gain of the West Papua economy from import-to-import input (Figure 5). The result is consistent with the fact that a massive share of the intermediate inputs in Indonesia was sourced domestically, and the production processes tended to rely more on domestic rather than foreign supplier [14].

The result indicates the economic correction of mitigation interventions to be in line with the NDC target will affect value-added of the community from local inputs, as well as the value-added from import benefiting the global economy. The economic benefit under the BAU scenario for local communities is 841.68 billion IDR in 2030, while under the EID scenario is lower at 668.82 billion IDR. The similar result will be experienced by the contribution of West Papua to the global economy. Under the BAU scenario, the added value from import will decrease from 232.44 billion IDR to 184.70 billion IDR from the base year of 2010 to the target year of 2030. Therefore, in order to guarantee the well-being of the local people in West Papua, as well as, the industrial sector contribution in West Papua for the growth of global economy outside West Papua, the EID scenario that helps minimize GHGs emissions need to be tandem with the effort to mitigate the effect of economic correction.
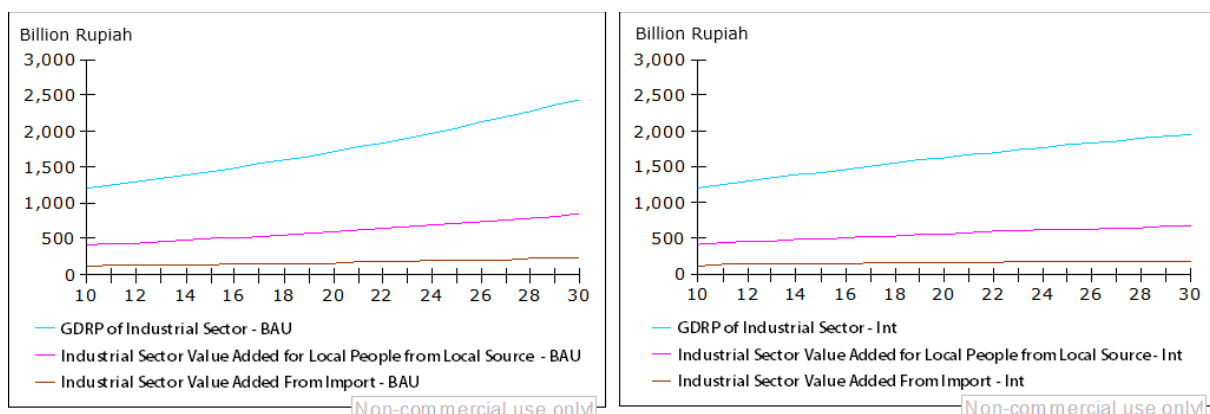
Figure 5. Results of the Intermediate Input simulation results on Industrial GRDP in West Papua.

4. Conclusion

The built system dynamics model in this study has successfully predicted the GRDP obtained if West Papua incorporates EID to mitigate emissions from the industrial sector and its shares to the local community's economy and the global economy. Based on the model simulations, the GRDP from industry sector under BAU will rise from about 1,200 billion IDR in 2010 to about 2,500 billion IDR in 2030, while under the EID intervention scenario, the regional income in the target year will be around 2,000 billion IDR. Regardless of lower economic return will be obtained under EID scenario, the simulation shows the potential exceeds in emissions from its threshold if West Papua does not implement EID scenario through 2030. It is projected that the GHGs emissions under the BAU scenario will steadily increase, reaching to 72,000 $tonCO_2e$, while the emissions threshold for 29% NDC target is about 69,0000 $tonCO_2e$. Meanwhile, the EID scenario under 29% and 41% NDC target will reduce emissions in the target year at 57,050 $tonCO_2e$ and 57,180 $tonCO_2e$ respectively, well below the emissions threshold. On the other hand, the implementation EID interventions scenario also brings impact to the added benefit for local communities and the contribution for the global economy through the integration of West Papua economy with global economy outside West Papua. The added benefit for local communities under EID scenario in 2030 will fall from 840 billion IDR under BAU scenario to 670 billion IDR while the contribution to outer region's economy under EID scenario in 2030 will also decrease from 230 billion IDR under BAU scenario to 180 billion IDR.

Based on the model prediction, this study suggests that the provincial government need to implement EID scenario to control the GHGs emission from the Industrial Sector and achieve NDC target in 2030. Besides, the study recommends that to guarantee the well-being of the local people in West Papua and the industrial sector contribution in West Papua for the growth of the global economy outside West Papua. The provincial government need to consider economic contraction by considering climate mitigation activities. Particularly synergizing the eco-industrial development with other programs in the provincial development plan (RPJMD) that can mitigate the side effect of economic correction from the implementation of EID scenario in the industrial sector. Besides, the future research needs to be enhanced to involve variables of environment and society in West Papua to in-depth explore its relationships with factor production of labour in the industrial sector.

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