TRACKING AND STRENGTHENING CLIMATE ACTION

(TASCA) DI PAPUA BARAT

15 Desember 2020

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KATA PENGANTAR

Program TASCA berencana untuk menerjemahkan inisiatif nasional ini di tingkat provinsi. Komitmen iklim nasional atau National Determined Contribution (NDC) membutuhkan kontribusi dari provinsi. Komitmen ini mencakup beberapa sektor seperti kehutanan, pertanian, energi, industry, dan limbah. Papua Barat sebagai provinsi yang memiliki area hutan yang luas, dapat berkontribusi kepada pencapaian komitmen nasional dengan menjaga dan mencegah alih fungsi hutannya. Selain itu, perencanaan-perencanaan di luar sektor lahan juga akan berpengaruh kepada pengeluaran emisi yang dihasilkan Papua Barat. Papua Barat tengah melakukan revisi terhadap Rencana Aksi Daerah untuk menurunkan Gas Rumah Kaca (RAD GRK) dan memperbaiki pelaporan emisinya (PEP GRK). Hasil-hasil tersebut diharapkan dapat mengeluarkan data-data emisi gas rumah kaca Papua Barat dan merumuskan narasi dan argumen yang kuat bahwa Papua Barat berkontribusi kepada pembangunan hijau nasional.

Merumuskan rencana pembangunan daerah yang berorientasi pada pembangunan rendah karbon perlu diimbangi dengan kapasitas sumber daya manusia di dalamnya. Pengembangan kapasitas ini diperlukan dalam meningkatkan pemahaman pemerintah dan pemangku kepentingan lokal terhadap konteks perubahan iklim dan kebijakan yang perlu dilakuan dalam pelaksanaan pembangunan yang berkelanjutan. Pengembangan kapasitas juga mencakup pengembangan kapasitas penggunaan model ekonomi, sosial dan lingkungan yang diharapkan dapat digunakan sebagai pendekatan yang berbasis sains untuk merumuskan proyeksi skema pembangunan Papua Barat yang terintegrasi. Sementara permodelan sistem spasial digunakan untuk menentukan lokasi yang sesuai untuk mengimplementasikan intervensi kebijakan. Sektor-sektor yang termasuk di dalam model dapat memuat sektor kehutanan, pertanian, energi, perikanan, industri, air, dan sebagainya, sesuai dengan kebutuhan Papua Barat. Pembangunan model dilakukan secara partisipati dengan melibatkan dinas-dinas provinsi Papua Barat dengan program-program yang mereka rencanakan.

Melalui ketiga tahap tersebut, Provinsi Papua Barat dapat diperlengkapi dengan analisa dan data-data yang lengkap untuk mendukung kontribusi Provinsi kepada komitmen nasional. Menghitung kontribusi Papua Barat terhadap aksi iklim nasional menjadi sangat penting sehingga dapat membantu pemerintah provinsi Papua Barat dalam menyusun aksi prioritas pembangunan daerah serta sebagai alat komunikasi yang penting kepada pemerintah nasional.

Semoga Kegiatan TASCA Tahap II ini dapat membantu pembangunan model pembangunan rendah karbon di Provinsi Papua Barat dalam menyusun aksi prioritas pembangunan daerah serta sebagai alat komunikasi yang penting kepada pemerintah nasional.

Manokwari, 15 Desember 2020

DAFTAR ISI

I. DESKRIPSI KEGIATAN

1.1. Pendahuluan/Latar Belakang

Pembangunan yang berorientasi pada pertumbuhan ekonomi dan kesejahteraan sosial telah menjadi pondasi bagi pembangunan Indonesia. Namun demikian, peran lingkungan hidup dan sumber daya alam merupakan indikator penting dalam memastikan terlaksananya pembangunan berkelanjutan dan mewujudkan Visi Indonesia tahun 2045. Untuk mengatasi permasalah pembangunan nasional, konteks Pembangunan Rendah Karbon (PRK) diperkenalkan sebagai upaya melibatkan aspek daya tampung dan daya dukung lingkungan hidup dalam pembangunan nasional. Konsep PRK Indonesia mengusung keseimbangan pilar-pilar keberlanjutan yakni ekonomi, lingkungan, dan sosial untuk mendukung iklim investasi hijau dan memperkuat integrasi lintas sektor (Bappenas, 2018).

Proses transisi menuju pembangunan Indonesia yang berkelanjutan dilaksanakan bertahap. Setelah diresmikannya PRK Indonesia di tingkat nasional pada Oktober 2018, proses selanjutnya adalah menerjemahkan isu PRK di tingkat sub-nasional, tak terkecuali di Provinsi Papua Barat. Sebagai salah satu wilayah dengan luas hutan terbesar di Indonesia, provinsi Papua Barat memiliki peran penting dalam menjaga kelestarian kawasan hutan dan ekosistem di dalamnya. Pada kontribusi daerah, sektor pertanian (termasuk kehutanan dan perikanan) berkontribusi terhadap 45% penyerapan tenaga kerja lokal atau sebesar 160.000 pekerja, dengan kontribusi terhadap perekonomian daerah menduduki peringkat keempat dari total PDRB yakni sebesar 7,8 milyar rupiah (BPS Provinsi Papua Barat, 2017). Manajemen pertanian yang tidak berkelanjutan dapat mengakibatkan berkurangnya hutan berharga yang dapat berakibat terhadap menurunnya pertumbuhan ekonomi dan ketersediaan lapangan pekerjaan.

Capacity building ‘Melacak dan Memperkuat Aksi Iklim’ (TASCA) di Papua Barat dilakukan untuk meresmikan inisiasi penyelenggaraan TASCA. Diseminasi program TASCA ini diharapkan dapat mendorong keterlibatan berbagai *stakeholder* lokal yang bergerak di isu iklim untuk bekerja sama dan berpartisipasi dalam mewujudkan pembangunan hijau di Papua Barat.

Pada tahun 2020, WRI dan UNIPA akan melakukan kegiatan pelatihan lanjutan untuk memperdalam pengetahuan dan praktis membangun skenario penurunan emisi di Papua Barat. Pelatihan ini rencananya akan disampaikan dalam 3 kali pertemuan, di bulan Juni, September dan Oktober 2020.

Dengan kondisi Pandemi COVID-19, pelatihan ini akan dilakukan secara *online* melalui medium aplikasi “zoom” dengan pertemuan pelatihan dilakukan beberapa kali, dengan fokus langsung pada model sosial, ekonomi dan lingkungan.

1.2. Tujuan Kegiatan

Tujuan dari kegiatan TASCA tahap II yaitu:

1. Permodelan pembangunan rendah karbon Papua Barat dari bidang ekonomi, sosial dan lingkungan.
2. Diseminasi output model Pembangunan Rendah Karbon di level region, nasional dan seminar internasional APIK Network.

1.3. Hasil yang Diharapkan

Hasil yang diharapkan dari kegiatan TASCA Tahap II yaitu :

- Model pembangunan rendah karbon di Provinsi Papua Barat berdasarkan kondisi social, ekonomi dan lingkungan.

1.4. Waktu dan Tempat Pelaksanaan

Pelaksanaan kegiatan Pelatihan Permodelan *System Dynamic* di selenggarakan pada:

Bulan : Juni, Septmber dan Oktober

Tempat : Zoom meeting, webinar

1.5. Agenda

Jadwal kegiatan Pelatihan Permodelan System Dynamic adalah sebagai berikut :

- Pelatihan Permodelan System Dynamic terbagi dalam 3 kelompok breakroom, yaitu social, ekonomi dan lingkungan untuk membahas SFD.

1.6. Peserta

Kegiatan TASCA Tahap II terkait Pelatihan Permodelan System Dynamic tersebut dikoordinir oleh 9 peserta dengan masing-masing kelompok (sosial, ekonomi dan lingkungan) berjumlah 3 orang yang terdiri dari analisis data, modeller, dan penanggung jawab kelompok.

II.LAPORAN FINAL DOKUMEN

KERTAS KERJA

Skenario Kontribusi Papua Barat untuk Pencapaian NDC

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1. Ringkasan Eksekutif

Ide Pokok

- Kontribusi para pihak tingkat subnasional sangat penting. Dalam skenario *unconditional*, jumlah target reduksi emisi diperhitungkan sebesar 834 mega ton CO_2e, dan reduksi emisi *conditional* sebesar 1,081 giga ton CO_2e (KLHK, 2017). Total reduksi emisi nasional ini merupakan jumlah atau agregasi reduksi emisi dari seluruh wilayah pembangunan tingkat sub nasional, yaitu provinsi dan kabupaten/kota.
- Meski peran para pihak pada tingkat subnasional sangat penting, namun Indonesia memiliki kondisi lingkungan, sosial, dan ekonomi yang bervariasi antar wilayah yang meningkatkan kompleksitas translasi NDC dari nasional ke subnasional. Skenario kontribusi pemerintah subnasional untuk NDC perlu didasarkan pada prinsip-prinsip '*common but differentiated responsibilitie*s (CBDR) and *respective capabilities* (RC). Integrasi holistik aspek lingkungan, sosial, dan ekonomi merupakan kunci utama untuk memastikan kontribusi tersebut adil dan ambisius (FA).
- Penelitian ini menggunakan metode *system dynamics* untuk membangun skenario kebijakan implementasi NDC Provinsi Papua Barat yang sesuai dengan rasionalitas lingkungan, sosial, dan ekonomi di wilayah tersebut.

Temuan utama

Total emisi Provinsi Papua Barat diperkirakan akan terus mengalami peningkatan lebih dari 24% ditahun 2030, dan terutama didominasi (58%) dari sektor kehutanan, jika tidak ada intervensi kebijakan iklim (BAU). Figur ini berbeda dengan skenario nasional, dimana sektor energi menjadi sumber emisi terbesar jika tidak ada intervensi iklim.

Total emisi maksimal di Provinsi Papua Barat diperkirakan mencapai 38.830.345 ton CO2 eq dalam kondisi BAU. Memperhatikan konteks lokal, baik dari aspek ekologis, sosiologis, dan perekonomian wilayah, pada tahun 2030 potensi reduksi emisi mencapai 24.762 mega ton CO2 eq atau sebesar 64% dari total emisi. Semua reduksi emisi tersebut mengandalkan dari sektor kehutanan, sedangkan dari sektor lain masih menunjukkan peningkatan emisi, untuk menjaga pertumbuhan ekonomi sebagai bekal transisi menuju perekonomian yang berkelanjutan. Artinya emisi Provinsi Papua Barat pada tahun 2030 diprediksikan mencapai 14.068 mega ton CO2 eq, dengan capaian reduksi emisi melampaui target nasional, yaitu 29%-41%. Oleh karena itu dukungan international sangat diperlukan untuk implementasi NDC di Provinsi Papua, agar kesejahteraan dan ketahanan masyarakat Provinsi Papua Barat terus dapat ditingkatkan dalam berkontribusi untuk pengendalian perubahan iklim global.

Dengan bantuan dari pihak lain (*conditiona*l/CM2), merujuk pada skenario reduksi emisi 29%, maka total emisi maksimal untuk Provinsi Papua Barat yaitu 11.261 ton CO2eq. Sehingga target reduksi emisi sebesar 64% dalam implementasi NDC Provinsi Papua Barat membutuhkan skema kemitraan internasional.

Berdasarkan skenario NDC subnasional Papua Barat yang dibangun berbasiskan konservasi ekosistem hutan (moratorium dan restorasi ekosistem hutan primer), maka akan terjadi pengurangan emisi sebesar 69% dari BAU dengan luasan hutan terjaga lebih luas dari syarat minimum yakni 8.777.239 hektar. Meski efektif mengurangi reduksi, namun diperkirakan skenario ini akan meningkatkan tingkat kemiskinan Papua Barat menjadi 12, 68 % (lebih tinggi dibandingkan perkiraan BAU: 10,75%) dengan IPM terkoreksi menjadi 74,52% (dibandingkan 75,19 BAU). PDRB akan terkontraksi -4% (sebesar 140,6 T) dibandingkan BAU.

Skenario kontribusi Papua Barat untuk pencapaian NDC dibangun berdasarkan pembangunan berkelanjutan yang berbasis intervensi kebijakan moratorium dan restorasi hutan primer ditambah dengan invervensi ekonomi misalnya intensifikasi pertanian. Skenario ini menemukan reduksi emisi yang lebih rendah yakni 64% dibandingkan skenario konservasi yakni 69%. Namun jika scenario ini diterapkan, maka tingkat kemiskinan Papua Barat akan menurun menjadi 10.26% dan IPM meningkat menjadi 76.33%. Sedangkan PDRB meningkat 15% menjadi 174,5%. Dengan penerapan skenario ini, luas hutan yang bisa dipertahankan tidak jauh berbeda dengan dari skenaro konservasi dan masih memenuhi *threshold* luas hutan minimal.

Rekomendasi

Dengan membandingkan hasil skenario *business as usual* (BAU), skenario konservasi ekosistem hutan dan skenario pembangunan berkelanjutan, bisa ditarik kesimpulan bahwa skenario pembangunan berkelanjutan merupakan skenario terbaik untuk kontribusi Papua Barat untuk pencapaian NDC. Dibawah skenario ini, total reduksi emisi Provinsi Papua Barat pada tahun 2030 mencapai 64% atau 24,76 mega ton CO2e. Dibawah skenario ini, Papua Barat masih bisa mencapai pertumbuhan ekonomi, perbaikan IPM serta PDRB dibandingkan dengan skenario konservasi. Intensifikasi pertanian serta pengembangan pertumbuhan ekonomi pada sektor yang selama ini tidak menjadi unggulan merupakan faktor utama yang mendorong perbaikan kondisi perekonomian di tahun 2030.

2. Komitmen Iklim Indonesia dan Peran Penting Pemerintah Subnasional

Indonesia memiliki hutan dengan keanekaragaman hayati yang paling beragam di dunia setelah Brasil dan Republik Demokratik Kongo. Global Forest Watch (GFW) mencatat bahwa pada tahun 2000, Indonesia memiliki 161 juta tutupan pohon, setara dengan 85% dari luas daratannya dan 4,0% dari total global. Meskipun demikian, tutupan hutan di Indonesia terus menurun. Pada tahun 2010, tutupan hutan Indonesia menurun menjadi 137 juta hektar hutan alam atau 73% dari luas daratannya (kehilangan 12 persen dalam satu dekade). Pada tahun 2018, Indonesia kehilangan 1.22 juta tutupan pohon, setara dengan 480 juta ton CO2eq dari emisi. GFW mencatat bahwa 340 kilo hektar (kha) dari kehilangan ini terjadi di dalam hutan primer dan 907 kha di dalam hutan alam. Hutan memegang peran penting dalam mengurangi emisi GRK secara global, studi Rizvi et al (2015) menunjukkan pentingnya hutan dalam menentukan akumulasi gas rumah kaca di atmosfer dan kemampuannya untuk menyerap 2,6 miliar ton CO2 setiap tahun (1/3 dari CO2 dilepaskan dari pembakaran bahan bakar fosil).

Indonesia adalah salah satu penghasil emisi terbesar di dunia gas rumah kaca (GRK). Selama dua dekade terakhir, emisi GRK meningkat dari hampir semua sektor, seperti penggunaan lahan (didefinisikan sebagai penggunaan lahan, perubahan penggunaan lahan, dan kehutanan, termasuk kebakaran gambut), energi, pertanian, industri, dan limbah (Wijaya et al, 2017). Meski saat ini, sektor penggunaan lahan mendominasi GRK emisi di Indonesia, tetapi analisis WRI menunjukkan energi pangsa sektor diproyeksikan meningkat menjadi lebih dari 50 persen total emisi pada tahun 2026-2027.

Indonesia telah membuat komitmen tanpa syarat dan kondisional untuk mengurangi emisi gas rumah kaca (Pemerintah Indonesia, 2016; Tacconi dan Muttaqin, 2019). Dalam NDC-nya, Indonesia berkomitmen:

- Mengurangi emisi GRK tanpa syarat sebesar 29 persen terhadap skenario BAU pada 2030 dan
- Mengurangi emisi GRK hingga 41 persen di bawah BAU 2030, jika didukung oleh bantuan internasional untuk keuangan, transfer teknologi, dan pengembangan kapasitas.

Dalam NDC Indonesia yang disahkan melalui UU No 16/2016 disebutkan bahwa target pengurangan emisi harus diperkuat dari waktu ke waktu untuk menjaga agar kenaikan suhu permukaan bumi tidak melebihi 2^0 Celcius dan mengupayakan dibawah $1{,}5^0$ Celcius. Artinya, para pihak harus memenuhi komitmen awal mereka dan meningkatkan ambisi iklim secara bertahap (*ratcheted mechanism*).

Target *First* NDC dapat dilihat pada Tabel 1 berikut ini.

Tabel 1 Target Reduksi Emisi GRK *First* NDC Indonesia Tahun 2030

No	Sektor	Tingkat Emisi GRK 2010	Tingkat Emisi GRK 2030 ($MTon\ CO_2e$)			Penurunan Emisi GRK				Rerata Pertum-buhan Tahunan BAU (2010-2030)	Rerata Pertum-buhan 2000-2012*
						($MTon\ CO_2e$)		% of Total BaU			
		$MTon\ CO_2e$	BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1	Energi*	453.2	1,669	1,355	1,271	314	398	11%	14%	6.7%	4.50%
2	Limbah	88	296	285	270	11	26	0.38%	1%	6.3%	4.00%
3	IPPU	36	69.6	66.85	66.35	2.75	3.25	0.10%	0.11%	3.4%	0.10%
4	Pertanian	110.5	119.66	110.39	115.86	9	4	0.32%	0.13%	0.4%	1.30%
5	Kehutanan**	647	714	217	64	497	650	17.2%	23%	0.5%	2.70%
	TOTAL	**1,334**	**2,869**	**2,034**	**1,787**	**834**	**1,081**	**29%**	**38%**	3.9%	3.20%

* Termasuk *fugitive* **Termasuk kebakaran gambut

Notes: **CM1**= *Counter Measure* 1 (kondisi skenario tanpa persyaratan mitigasi-*unconditional*)
CM2= *Counter Measure* 2 (kondisi skenario dengan persyaratan mitigasi-*conditional*)

Sumber: Pemerintah Indonesia (2016)

Ada beberapa prinsip NDC yang telah disepakati. Prinsip pertama adalah "*common but differentiated responsibilities"* (CBDR). Prinsip ini mempertimbangkan perbedaan tanggungjawab setiap negara dalam upaya mencapai tujuan utama bersama penanganan perubahan iklim. Selanjutnya dalam skema NDC, prinsip CDBR berkembang menjadi "*common but differentiated responsibilities and respective capabilities"* (CBDR & RC), untuk mempertimbangkan aspek lainnya, yaitu kapabilitas, sesuai konteks masing-masing negara.

Selain berdasarkan prinsip CBDR & RC, komitmen Indonesia 29% unconditional dan 41% conditional dibangun berdasarkan kriteria Fair and Ambitious (FA) dengan berpedoman pada prinsip berikut: (1) *Decision 1/CP. 20, Article 14.*, dinyatakan *"…and how the Party considers that its intended nationally determined contribution is fair and ambitious, in light of its national circumstances…"*, (2) *Decision: 1/CP. 19, Article 2b.,* yang menyatakan *"…. And to communicate them well in advance of the twenty-first session of the Conference of the Parties in a manner that facilitate the clarity, transparency, and understanding of the intended contribution." (3)* dan juga pada *Decision 1/CP. 20, Article 14.*, yang menyepakati implikasi cakupan informasi yang perlu disajikan dalam rangka memenuhi kriteria *Clarity, Transparency, dan Understandable* (CTU). Prinsip CBDR & RC serta kriteria CTU & FA menjadi landasan dalam mengidentifikasi isu-isu strategis dan formulasi kebijakan strategis implementasi NDC di Indonesia.

Kontribusi para pihak ditingkat subnasional sangat penting dalam pencapaian NDC Indonesia. Dalam scenario unconditional, jumlah target reduksi emisi diperhitungkan sebesar 834 mega ton CO2e, dan reduksi emisi *conditional* sebesar 1,081 giga ton CO2e (Pemri, 2017). Total reduksi emisi nasional ini merupakan jumlah atau agregasi reduksi emisi dari seluruh wilayah pembangunan tingkat sub nasional, yaitu provinsi dan kabupaten/kota.

Meski peran para pihak pada tingkat subnasional sangat penting, namun Indonesia memiliki kondisi lingkungan, sosial, dan ekonomi yang bervariasi antar wilayah yang meningkatkan kompleksitas translasi NDC dari nasional ke subnasional. Karenanya, prinsip CBDR & RC menjadi penting tidak hanya pada tataran global, namun juga untuk melandasi implementasi ditingkat subnasional. Oleh karena itu, prinsip CBDR & RC, tidak hanya untuk kepentingan konteks Indonesia untuk upaya global, namun juga menjadi prinsip implementasi di tingkat subnasional. Dalam menerjemahkan NDC ke tataran subnasional, implementasi NDC perlu secara bersamaan mendorong agenda lingkungan, sosial, dan ekonomi di wilayah provinsi.

Kertas kerja ini akan membahas skenario kontribusi Papua Barat dalam pencapaian NDC Indonesia. Dengan mempertimbangkan prinsip CBDR & RC, kontribusi Provinsi Papua Barat perlu mempertimbangkan konteks lokal yang berbeda dengan provinsi lainnya dalam aspek lingkungan, sosial, dan ekonomi. Pulau Papua memegang peranan kunci dalam pencapaian NDC, dengan tutupan hutan hujan tropis dan komitmen politik untuk mewujudkan Provinsi Konservasi yang kuat. Tutupan hutan total di Provinsi Papua Barat mencapai 90 persen dari total luas wilayah, dengan total 8,9 juta hektar. Angka ini mencakup semua tutupan hutan di dalam kawasan hutan negara dan non-hutan (Steni Bernadinus & Nepstad Daniel, 2018). Disisi lain, Papua Barat masih menduduki provinsi dengan tingkat kemiskinan kedua tertinggi dan provinsi dengan indeks sumber daya manusia terendah nasional kedua. Dalam periode 2010-2018, ada beberapa perbaikan ekonomi dan pertumbuhan PDRB yang patut dicatat yakni 11.87% kenaikan pertumbuhan ekonomi dan 19 miliar pertumbuhan PDRB (BPS, 2020). Kondisi ini menjelaskan masih besarnya kebutuhan

Provinsi Papua Barat untuk mencapai potensi pertumbuhan ekonomi maksimal dan perbaikan kualitas sumber daya manusia yang perlu diselaraskan dengan kepentingan nasional terkait pencapaian target iklim.

Implementasi NDC Subnational atau Rencana Mitigasi dan Adaptasi Provinsi Papua Barat perlu menggunakan pendekatan yang memenuhi kriteria holistik dan mampu mengintegrasikan interaksi antar aspek lingkungan, sosial, dan ekonomi. Paradigma *Systems Thinking* dengan Metode *System Dynamics* memiliki kriteria yang dibutuhkan tersebut. Menggunakan paradigma *Systems Thinking* dengan Metode *System Dynamics* diharapkan dapat menghasilkan kebijakan implementasi NDC Provinsi Papua Barat yang sesuai dengan rasionalitas lingkungan, sosial, dan ekonomi di wilayah tersebut.

Laporan ini ingin mendapatkan pandangan yang lebih dalam tentang potensi karbon Papua Barat dan menilai kebijakan kunci apa yang diperlukan untuk memungkinkan provinsi menikmati pertumbuhan ekonominya sambil juga melestarikan hutan mereka. Secara khusus, laporan ini ingin menjawab pertanyaan penelitian berikut:

1. Seberapa besar prediksi emisi dari Provinsi Papua Barat dalam kondisi business as usual (BAU)?
2. Seberapa besar proyeksi kontribusi emisi dari Provinsi Papua Barat jika menggunakan skenario konservasi provinsi (CM1) versus skenario pembangunan berkelanjutan (CM2)
3. Apakah implikasi kebijakan di bawah setiap pilihan skenario yang diusulkan dengan mempertimbangkan prinsip-prinsip yang adil dan ambisius (FA)?

3. Pendahuluan: Isu Strategis Implementasi NDC di Papua Barat

Provinsi Papua Barat adalah wilayah pemekaran Provinsi Papua (UU No 45/1999) dan Instruksi Presiden Nomor 1 Tahun 2003 Tentang Percepatan Pelaksanaan Undang-Undang Nomor 45 Tahun 1999 Tentang Pembentukan Provinsi Irian Jaya Tengah, Provinsi Irian Jaya Barat, Kabupaten Paniai, Kabupaten Mimika, Kabupaten Puncak Jaya, dan Kabupaten Sorong. Pada akhirnya, dengan nama Provinsi Papua Barat, terbentuk menjadi provinsi secara penuh setelah dilantiknya Gubernur dan Wakil Gubernur pada tanggal 24 Juli 2006.

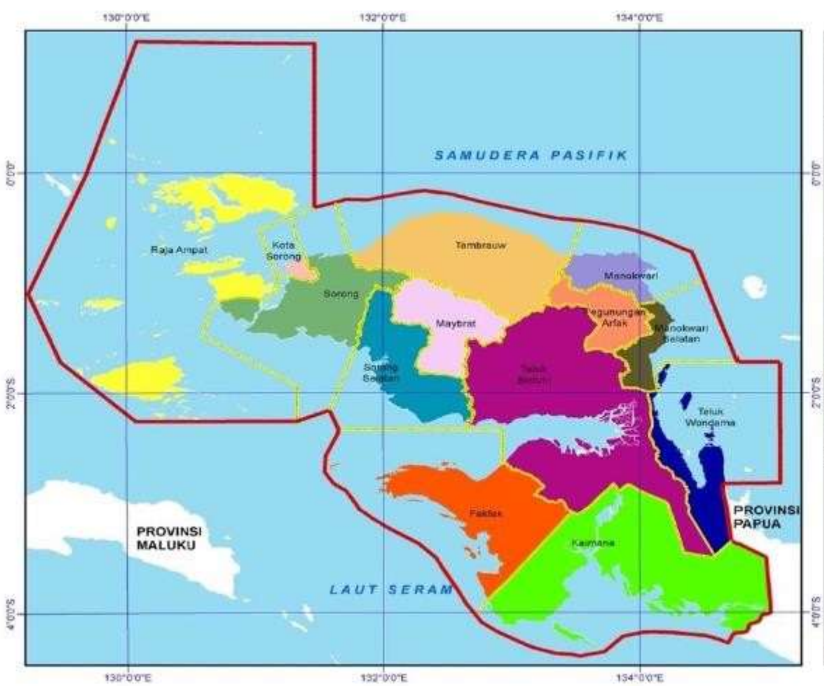
Sampai dengan tahun 2017, Provinsi Papua Barat terdiri atas 13 kabupaten/kota dengan total luas wilayah 99,672 km^2 atau 9.967.163 juta hektar (Tabel 2), dengan Ibukota Manokwari.

Tabel 2. Sebaran Luas Wilayah Kabupaten/Kota di Provinsi Papua Barat

No.	Kabupaten/Kota	Luas (km²)	Persentase (%)
1.	Fakfak	11,036.48	11.07
2.	Kaimana	16,241.84	16.30
3.	Teluk Wondama	3,959.53	3.97
4.	Teluk Bintuni	20,840.83	20.91
5.	Manokwari	3,186.28	3.20
6.	Sorong Selatan	6,594.31	6.62
7.	Sorong	6,544.23	6.57
8.	Raja Ampat	8,034.44	8.06
9.	Tambrauw	11,529.18	11.57
10.	Maybrat	5,461.69	5.48
11.	Manokwari Selatan	2,812.44	2.82
12.	Pegunungan Arfak	2,773.74	2.78
13.	Kota Sorong	656.64	0.66
	Papua Barat	99,671.63	100,00

Sumber: Bappeda Papua Barat (2017)

Provinsi Papua Barat sebagian besar berbatasan dengan Samudra Pasifik di sebelah utara dan sebagian timur, serta Laut Seram di sebelah barat sampai selatan. Sedangkan daratan sebelah timur berbatasan dengan Provinsi Papua (Gambar 1). Sebagian wilayah Provinsi Papua Barat, khususnya Kabupaten Raja Ampat terletak di pusat segitiga karang dunia (*coral triangle*) yaitu wilayah dengan keanekaragaman hayati laut terkaya di dunia.

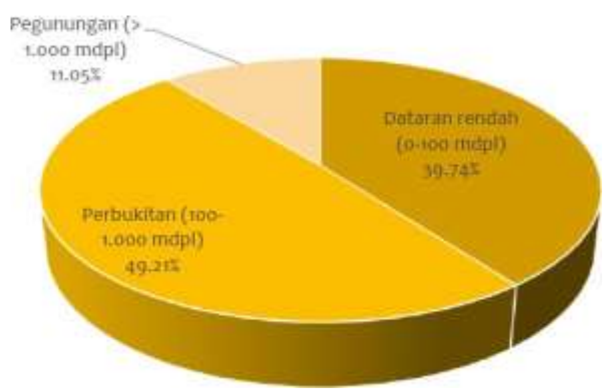


Sumber: Bappeda Papua Barat (2017)

Gambar 1. Peta Wilayah Administratif Provinsi Papua Barat 2017

Kondisi wilayah Provinsi Papua meliputi wilayah pedalaman/terpencil (pegunungan), pesisir, dan kepulauan. Wilayah pedalaman/terpencil (pegunungan) di Provinsi Papua Barat diantaranya berada di Kebupaten Pegunungan Arfak, Manokwari, Manokwari Selatan, Maybrat, Teluk Bintuni, dan Tabrauw. Sedangkan wilayah yang memiliki pesisir yaitu Kabupaten Sorong, Sorong Selatan, Fakfak, Kaimana, Teluk Bintuni, Teluk Wondama, Manokwari Selatan, Manokwari, Tambrauw, Raja Ampat, dan Kota Sorong. Terdapat satu wilayah berupa kepulauan yaitu Kabupaten Raja Ampat. Secara umum, berdasarkan jumlah dan sebaran kampung, masyarakat Provinsi Papua Barat lebih dominan tinggal di pegunungan dan daratan bukan tepi pantai, yang mencapai 1.024 kampung. Sedangkan kampung yang berada di tepi laut berjumlah lebih sedikir, yaitu 543 kampung.

Berdasarkan topografinya, Provinsi Papua Barat kondisinya sebagian besar termasuk dalam wilayah perbukitan (kelas ketinggian 100-1.000 meter) dengan cakupan areal mencapai 47.741 km^2. Sedangkan wilayah yang masuk dalam daerah dataran rendah seluas 38.560 km^2, sisanya berupa daerah pegunungan yaitu 11,05% (Gambar 2).



Sumber: Bappeda Papua Barat (2017)

Gambar 2. Sebaran Kondisi Topografi Provinsi Papua Barat

Kondisi tutupan lahan di Provinsi Papua didominasi oleh hutan lahan kering primer, mencapai 7,2 juta hektar dari 9,7 juta hektar daratan atau mencapai 74%. Areal pertanian masih relatif sedikit, demikian juga penggunaan lahan untuk permukiman yang hanya mencapai 32.222 hektar. Perincian penggunaan lahan Provinsi Papua tahun 2014 dapat dilihat pada Tabel 3 berikut ini.

Tabel 3. Kondisi Penggunaan Lahan di Provinsi Papua Barat Tahun 2014.

No.	Penggunaan Lahan	Luas (Km²)
1.	Hutan Lahan Kering Primer	71.792,39
2.	Hutan Lahan Kering Sekunder	14.168,92
3.	Hutan Lahan Basah Primer	3.251,11
4.	Hutan Lahan Basah Sekunder	1.627,28
5.	Perkebunan Campuran	425,97
6.	Perkebunan	630,37
7.	Ladang	540,09
8.	Tanaman Campuran	485,96
9.	Permukiman	322,22
10.	Padang Rumput/Alang-Alang	9,66
11.	Semak dan Belukar	2.135,22
12.	Danau	202,23
13.	Lahan Terbuka	1.181,43
14.	Pertambangan	21,19
15.	Rawa	41,63
16.	Rumput Rawa	67,78
17.	Sawah	120,84
Jumlah		**97.024,27**

Sumber: Bappeda Papua Barat (2017)

Total jumlah penduduk Provinsi Papua pada tahun 2018 mencapai 937.458 jiwa, dengan angka laju pertumbuhan penduduk 2,57% pada periode 2010-2018, relatif lebih tinggi dibandingkan dengan laju pertumbuhan penduduk pada tingkat Nasional. Hampir 20% penduduk tinggal di Kota Manokwari, sedangkan lainnya tersebar di 12 Kabupaten lainnya (Tabel 4). Provinsi Papua Barat menjadi salah satu provinsi dengan kepadapatan rendah, yaitu 9,11 jiwa/km^2.

Tabel 4. Jumlah dan Sebaran Penduduk Provinsi Papua Barat Tahun 2018

Kabupaten/Kota *Regency/Municipality*	Penduduk (ribu) *Population (thousand)*			Laju Pertumbuhan Penduduk per Tahun *Annual Population Growth Rate*	
	2010[1]	2015[2]	2018	2010 - 2015	2010 - 2018
(1)	(2)	(3)	(4)	(5)	(6)
Kabupaten/*Regency*					
1 Fakfak	66 393	73 468	77 381	2,05	1,93
2 Kaimana	47 107	54 165	58 404	2,83	2,72
3 Teluk Wondama	26 425	29 791	31 769	2,43	2,33
4 Teluk Bintuni	52 619	59 196	63 091	2,38	2,29
5 Manokwari	138 184	158 326	170 897	2,76	2,69
6 Sorong Selatan	38 121	43 036	46 021	2,46	2,38
7 Sorong	70 866	80 695	86 994	2,63	2,60
8 Raja Ampat	42 076	45 923	47 885	1,77	1,63
9 Tambrauw	12 961	13 615	13 804	0,99	0,79
10 Maybrat	33 332	37 529	40 102	2,40	2,34
11 Manokwari Selatan	19 234	21 907	23 617	2,64	2,60
12 Pegunungan Arfak	24 772	28 271	30 409	2,68	2,60
Kota/*Municipality*					
71 Kota Sorong	193 168	225 588	247 084	3,15	3,12
Papua Barat	765 258	**871 510**	**937 458**	2,63	2,57

Sumber: BPS Papua Barat (2019)

Menjadi catatan khusus untuk Provinsi Papua Barat dalam aspek kondisi sosial, yaitu angka kemiskinan yang tinggi, mencapai 35,71% pada tahun 2009 dan masih berada jauh di atas kondisi Nasional, yaitu mencapai 23,01% pada tahun 2018. Tentunya, kemiskinan menjadi perhatian Provinsi Papua Barat, dan menjadi konteks utama dalam aspek sosial. Selain hal penting lainnya adalah Indeks Pembangunan Manusia (IPM) pada tingkat 63,74, yang berarti berada pada urutan kedua terendah setelah Provinsi Papua. Berdasarkan komponennya, rendahnya IPM adalah Umur Harapan Hidup (UHH) yaitu hanya pada tingkat 65,6 tahun serta rendahnya aspek Pendidikan dan daya beli.

Tabel 5. Penduduk Miskin di Provinsi Papua Tahun 2009-2018

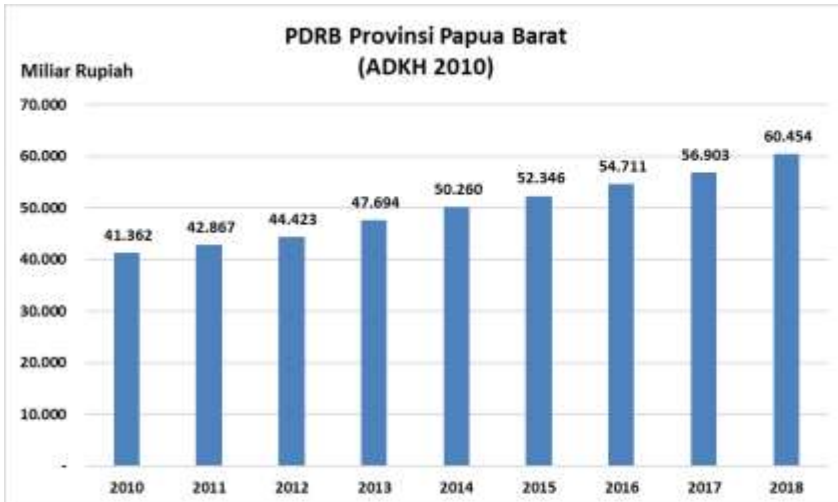
Tahun [1] *Year* [1]	Garis Kemiskinan (rupiah/kapita/bulan) *Poverty Line (rupiah/capita/month)*	Jumlah Penduduk Miskin (ribu) *Number of Poor People (thousand)*	Persentase Penduduk Miskin *Percentage of Poor People*
(1)	(2)	(3)	(4)
2009	277.416	256,84	35,71
2010	294.727	256,25	34,88
2011	318.796	249,84	31,92
2012	333.485	229,99	28,20
2013	363.929	224,27	26,67
2014	397.662	229,43	27,13
2015	441.569	225,36	25,82
2016	474.967	225,80	25,43
2017	499.778	228,38	25,10
2018	516.362	214,47	23,01

Sumber: BPS Papua Barat (2019)

Pada tahun 2018 jumlah angkatan kerja mencapai 417.544 orang, dengan dominasi pada lapangan pekerjaan sektor pertanian, yaitu 140.447 orang atau 33,64%, dan tentu saja akan memiliki relevansi dengan pengentasan kemiskinan. Berdasarkan hasil analisis pembangunan wilayah Provinsi Papua Barat (Provinsi Papua Barat, 2015), mayoritas penduduk bekerja bergantung pada sektor pertanian, yang memiliki produktivitas rendah, sehingga belum mampu mendorong kesejahteraan pekerja.

Produk Domestik Regional Bruto (PDRB) Provinsi Papua Barat terus mengalami peningkatan dengan dominasi dari industri pengolahan, pertambangan dan penggalian, serta bidang konstruksi. Sedangkan pertanian yang menjadi lapangan kerja mayoritas penduduk hanya berada pada urutan empat, dengan nilai Rp. 10,46 triliun.

Gambar 3. Produk Domestik Regional Bruto (PDRB) Provinsi Papua Barat



Sumber: BPS Papua Barat (2019)

Pertumbuhan PDRB menjadi isu strategis karena angka pertumbuhannya yang sangat tinggi, mencapai 10,94% pada tahun 2018. Angka pertumbuhan PDRB mengalami fluktuasi, namun secara umum mengalami peningkatan dari tahun 2014 yang mencapai 9,78%. Bahkan pertumbuhan PDRB mengalami peningkatan hampir dua kali lipat untuk tahun 2018 jika dibandingkan dengan tahun 2016 yang mencapai 5,95%. Berdasarkan jenis pengeluarannya, ekspor barang dan konsumsi rumah tangga serta konsumsi pemerintah menjadi pilar PDRB, bahkan ekspor barang mencapai 62% dari nilai PDRB.

4. Metodologi

4.1 Mengenai konsep system dynamics

System Dynamics adalah metode yang berlandaskan paradigma *Systems Thinking*. Menurut definisi Sterman (2004), *System Dynamics* adalah metode untuk mempelajari sistem yang kompleks, dengan berlandaskan pada teori *non-linier dynamics* dan *feedback control*. Martin (1997) mendefinisikan *System Dynamics* sebagai suatu metodologi yang digunakan untuk memahami suatu sistem yang berubah seiring dengan perubahan waktu atau dinamis. Sistem didefinisikan sebagai kumpulan dari bagian-bagian yang bekerja secara bersama-sama untuk tujuan tertentu (Forrester, 1971).

Ciri dari sistem yang dipelajari dan dimodelkan dalam model *System Dynamics* adalah sistem yang kompleks, memiliki perilaku dinamis dan *non-linier*, serta memiliki *feedback*, atau sistem tertutup (*feedback closed system*). *System Dynamics* berfokus pada struktur (*structure*) dan perilaku (*behavior*) dari sebuah sistem yang terbentuk dari umpan balik yang berinteraksi (Goodman, 1997). Penggunaan metode *System Dynamics* ditujukan untuk mempelajari dan memperoleh solusi atas suatu permasalahan atau kebijakan dari suatu sistem yang kompleks, dinamis melalui pegendalian *feedback*.

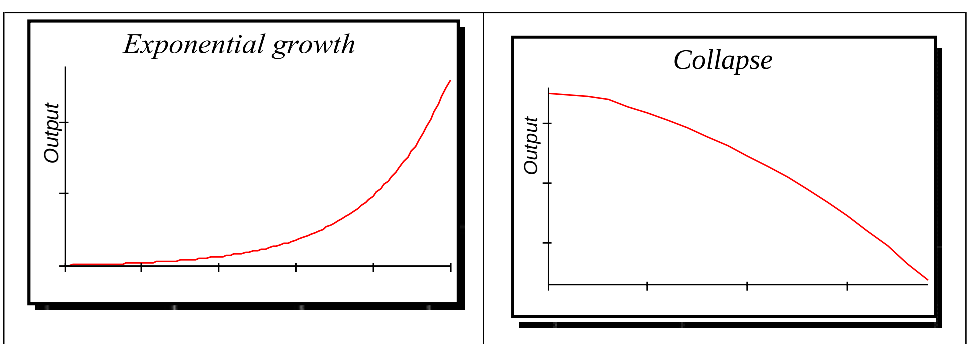
Dua tahapan utama dalam metode *System Dynamics* yaitu tahap *from story to structure* dan tahap *from structure to behavior*. Dalam tahap pertama *from story to structure* atau disebut juga tahap konseptualisasi, menghasilkan *Causal Loop Diagram* (CLD). Pada tahap selanjutnya, yaitu *from structure to behavior*, adalah tahap membangun *Stock Flow Diagram* (SFD) berdasarkan prinsip konsistensi struktur, yang kemudian disimulasikan untuk menirukan kinerja dan perilaku atau *behavior* dari sistem yang dimodelkan.

4.2 Konseptualisasi Permodelan

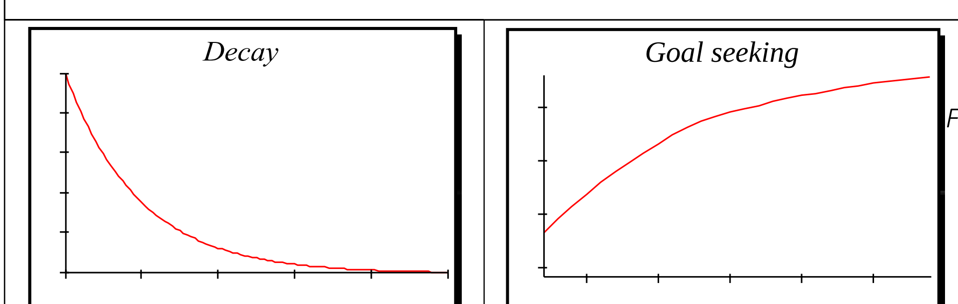
Konseptualisasi dalam permodelan *System Dynamics* menurut Albin (1997), memiliki empat tahapan, yaitu penetapan tujuan membuat model, menetapkan batasan sistem dan variabel utama, memperoleh gambaran pola referensi dengan menggunakan variabel utama, dan terakhir adalah menyusun struktur sistem yang membentuk suatu *loop*. Konseptualisasi juga sebagai tahap *from story to structure*, atau tahapan untuk menghasilkan CLD.

Keluaran konseptualisasi adalah CLD yaitu gambaran struktur sistem yang ditirukan atau dimodelkan dengan memuat unsur-unsur atau variabel utama, sifat hubungan antar variabel, *feedback loop* serta sifat *feedback loop* yang terbentuk. Terdapat dua sifat *feedback loop* yang terbentuk, yaitu *Balance* (B) yang bersifat menjaga stabilitas status sistem (*stability*) dan *Reinforce* (R) yang bersifat memperkuat status sistem (*instability*). Masing-masing sifat *feedback loop* memiliki perilaku dasar yang berbeda (Gambar 4). *Feedback loop Reinforce* memiliki perilaku *exponential growth* dan *collapse*. Sedangkan *feedback loop Balance* memiliki perilaku *goal seeking* dan *decay*.

Gambar 4. Perilaku Dasar *Feedback Loop Balance* dan *Reinforce*



Perilaku *reinforcing* (R) dari proses *feedback* positif



Output

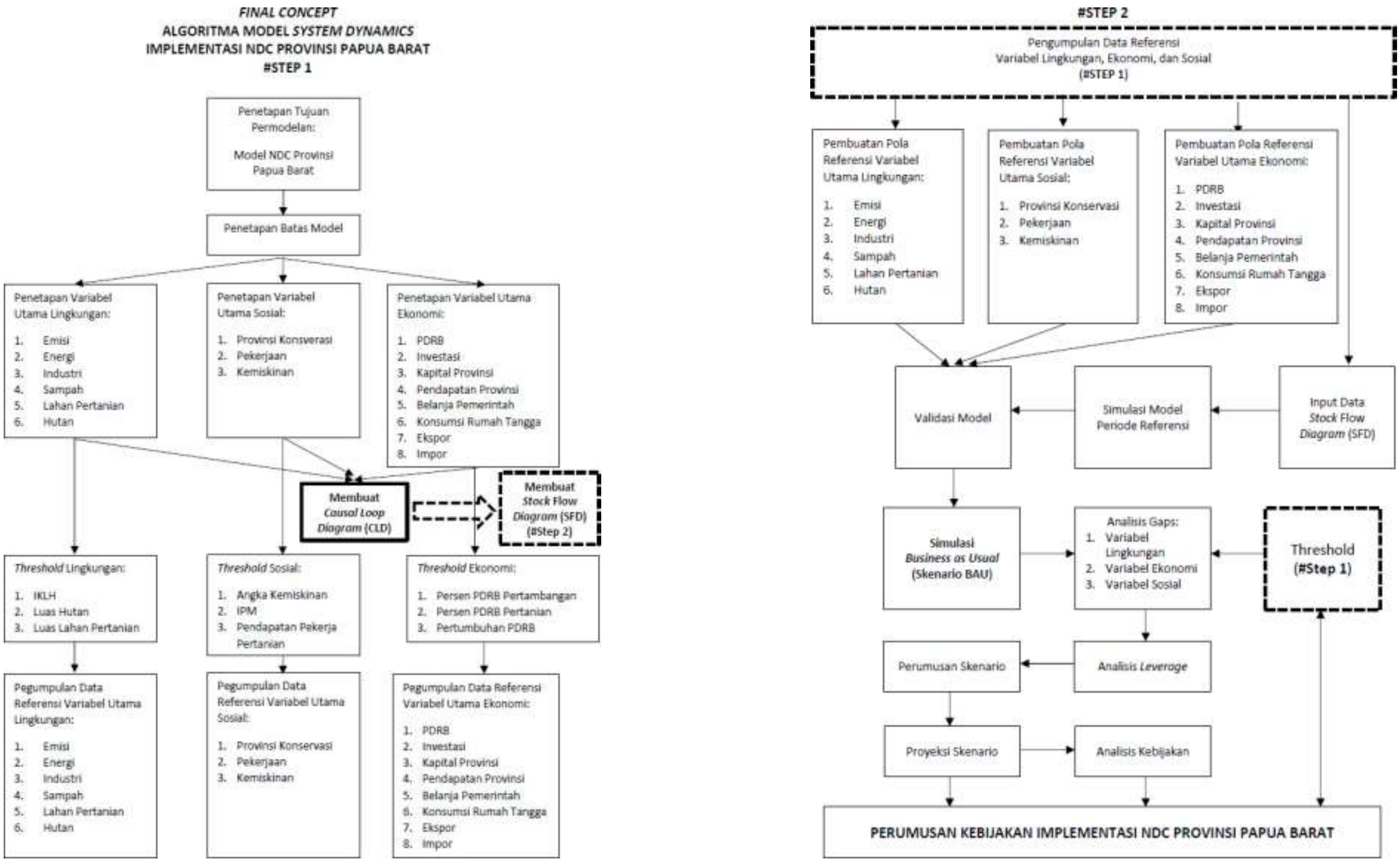
Output

Sumber: Dimodifikasi dari Forester (1971) dan Sterman (2004)

4.3 Deskripsi Sistem NDC Subnasional Provinsi Papua Barat

Dalam system dinamik, model dibangun sebagai tiruan dari system sebuah obyek atau fenomena yang diamati berlandaskan pada paradigma system thinking. Fenomena atau obyek yang ditirukan merupakan bagian dari sebuah system. Dalam hal ini, system yang ingin ditirukan adalah system implementasi NDC di Provinsi Papua Barat, yang merupakan turunan dari NDC Indonesia. Dalam mendekati system implementasi NDC, kita juga harus memperhitungkan sistem pembangunan mengingat aktifitas pembangunan disuatu wilayah akan mempengaruhi tingkat emisi disuatu wilayah. Artinya konsep NDC tidak hanya didasarkan pada aspek perubahan iklim (lingkungan) namun juga Perlu mengintegrasikan dengan aspek sosial dan ekonomi.

Berdasarkan paradigma *Systems Thinking* dan konsep pembangunan berkelanjutan, permodelan *System Dynamics* ini akan menirukan sistem pembangunan berkelanjutan di Provinsi Papua, namun dibatasi pada domain implementasi NDC di tingkat subnasional (gambar 5).



Gambar 5: Konsep algoritma system dynamic model untuk implementasi NDC di Papua Barat

4.4 Tujuan Permodelan

Permodelan ditujukan untuk memahami, memprediksi, dan mengoptimasi tingkat emisi gas rumah kaca di Provinsi Papua Barat dengan berlandaskan pada *threshold* lingkungan, sosial, dan ekonomi serta rasionalitas pembangunan berkelanjutan di Provinsi Papua Barat. Selanjutnya hasil permodelan akan digunakan sebagai dasar formulasi kebijakan NDC Provinsi Papua Barat dan implementasinya, juga sebagai dasar kebijakan Pembangunan Rendah Karbon Provinsi Papua Barat.

4.5 Pembatasan Sistem dan Variabel Utama

Dari langkah 1 dan 2 yang digambarkan dalam gambar 5, sistem yang dimodelkan dibatasi pada kriteria Implementasi NDC Provinsi Papua Barat. Variabel utama mengalami penyaringan berikutnya berdasarkan hasil *Fokus Group Discussion* (FGD) para ahli dan *stakeholders* bidang lingkungan, sosial, dan ekonomi, maupun isu strategis serta Prinsip, Kriteria, dan Indikator Implementasi NDC Provinsi Papua Barat serta ketersediaan data resmi yang bisa dipertanggungjawabkan. Variabel utama Draft Model Implementasi NDC Provinsi Papua Barat sebagai berikut (Tabel 6).

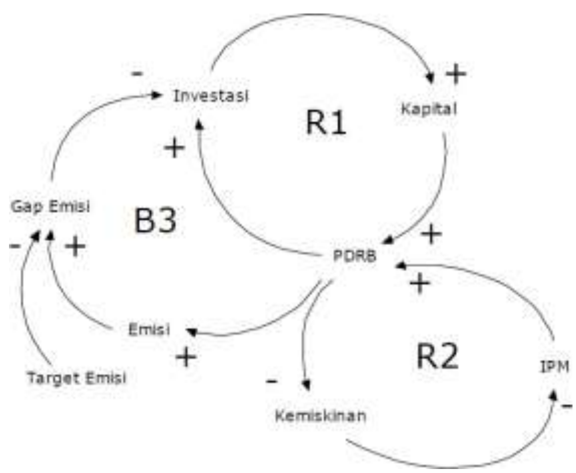
Tabel **6.** Variabel Model Implementasi NDC Provinsi Papua Barat

<table>
<tr><th rowspan="2">No</th><th colspan="2">Prinsip Lingkungan: Keberlanjutan fungsi dan manfaat sumber daya alam dan jasa lingkungan</th></tr>
<tr><th>Kriteria Lingkungan</th><th>Variabel Utama Lingkungan</th></tr>
<tr><td>1</td><td>Terjaganya kualitas lingkungan hidup
pada kondisi sangat baik</td><td rowspan="3">1.1. Luas Hutan
1.2. Erosi
1.3. Emisi (total emisi CO_2 ekuivalen)
1.4. Emisi Energi (emisi CO_2 ekuivalen Energi)
1.5. Emisi Sampah (emisi CO_2 ekuivalen Sampah)
1.6. Emisi Industri (emisi CO_2 ekuivalen Industri)
1.7. Emisi Pertanian (emisi CO_2 ekuivalen Pertanian)
1.8. Emisi Kehutanan (emisi CO_2 ekuivalen Pertanian)
1.9. Kecukupan Lahan Pertanian</td></tr>
<tr><td>2</td><td>Terjaganya fungsi dan manfaat ekosistem hutan dan lahan untuk
masyarakat</td></tr>
<tr><td>3</td><td>Tercukupinya lahan pertanian untuk kesejahteraan petani</td></tr>
<tr><th rowspan="2">No</th><th colspan="2">Prinsip Sosial : Terwujudnya kualitas sumber daya manusia yang maju</th></tr>
<tr><th>Kriteria Sosial</th><th>Variabel Utama Sosial</th></tr>
<tr><td>1</td><td>Berkurangnya penduduk miskin</td><td rowspan="2">1.1. Indeks Pembangunan Manusia
1.2. Kemiskinan (persen penduduk miskin)</td></tr>
<tr><td>2</td><td>Kualitas Sumber Daya Manusia</td></tr>
</table>

3	Kesejahteraan pekerja sektor pertanian	1.3. Penduduk Miskin (jumlah penduduk miskin)
No	**Prinsip Ekonomi: Pembangunan ekonomi yang cepat, merata, dan berbasiskan keberlanjutan kapital alam**	
	Kriteria Ekonomi	**Variabel Utama Ekonomi**
1	Berkurangnya ketergantungangan pada sektor pertambangan	1.1. PDRB 1.2. Investasi 1.3. PDRB Pertambangan 1.4. PDRB Industri 1.5. PDRB Konstruksi 1.6. PDRB Pertanian 1.7. PDRB Kehutanan 1.8. PDRB Pendidikan, Kesehatan dan Sosial
2	Peningkatan produktivitas sektor pertanian	
3	Peningkatan investasi	
4	Pengembangan infrastruktur	
5	Peningkatan Belanja Modal Daerah	

4.6 *Submodel ekonomi-lingkungan dan sosial NDC Papua Barat*

Causal Loop Diagram (CLD) secara lengkap terdiri atas 3 sub CLD, yaitu CLD Lingkungan, CLD Sosial, dan CLD Ekonomi, seperti terlihat pada Gambar 6.1. sebagai berikut.



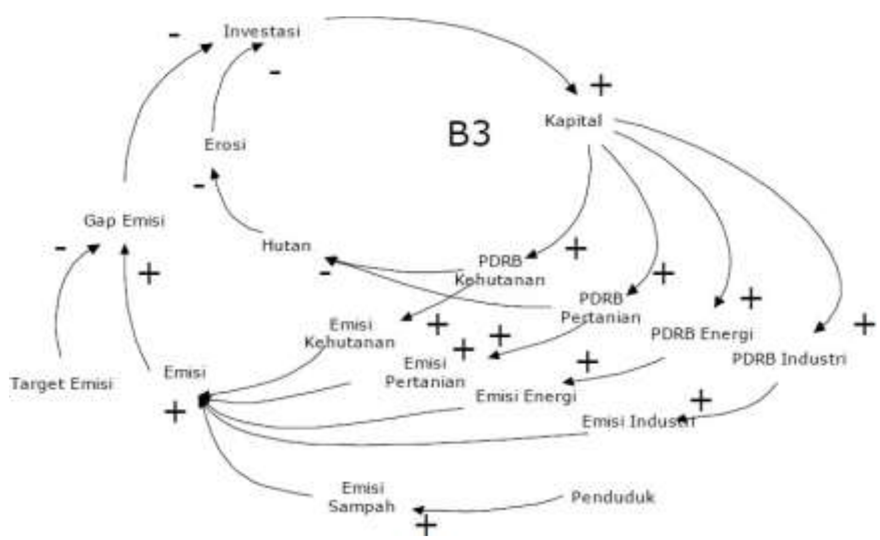
Gambar 6.1. CLD NDC Subnasional Provinsi Papua Barat

Dalam CLD Model Implementasi NDC Provinsi Papua Barat terlihat *feedback loop* R1 yang menunjukkan sifat perilaku umum sistem ekonomi, khususnya hubungan antara investasi-kapital- pendapatan. Ketertinggalan ekonomi saat ini terjadi karena rendahnya investasi dalam jangka waktu yang cukup lama (Supriadi, 2016). Dalam *feedback loop* R2, angka kemiskinan terjaga masih besar karena rendahnya investasi di sektor pertanian, dan lebih khusus, sebaliknya investasi terbesar berada pada sektor pertambangan yang tidak menjadi tumpuan lapangan pekerjaan penduduk miskin (Sagrim et al 2016).

PDRB memuat berbagai aktivitas pembangunan yang berimplikasi pada peningkatan konsumsi energi, perkembangan industri, produksi sampah, pembukaan lahan pertanian, dan deforestasi, yang semuanya menjadi sumber emisi. Mitigasi emisi secara umum dituangkan dalam kebijakan Provinsi Konservasi, untuk mempertahankan stok karbon, serta fungsi ekosistem hutan lainnya. Kebijakan Provinsi Konservasi ini, menurut Peraturan Daerah Provinsi (Perdasus) no 10 tahun 2019, dilakukan dengan mengendalikan investasi, khususnya yang dapat memperbesar pembukaan lahan atau deforestasi. Kebijakan ini bisa berimplikasi pada terbatasnya kegiatan ekonomi sektor pertanian yang menjadi tumpuan penduduk miskin.

Sub model lingkungan

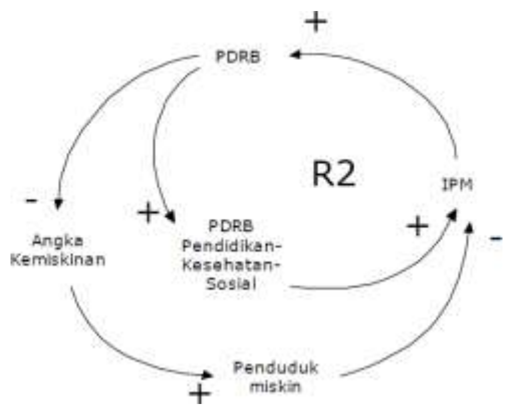
Pada CLD Lingkungan (Gambar 6.1a), sesuai dengan pembatasan permodelan fokus pada 5 sektor emisi, yaitu emisi energi, sampah, industri, pertanian, dan kehutanan. Keterkaitan CLD Lingkungan dengan CLD Ekonomi adalah melalui variabel PDRB. Sedangkan keterkaitan CLD Lingkungan dengan CLD Sosial adalah melalui variabel jumlah penduduk.



Gambar 6.1a. CLD Lingkungan

Sub model sosial

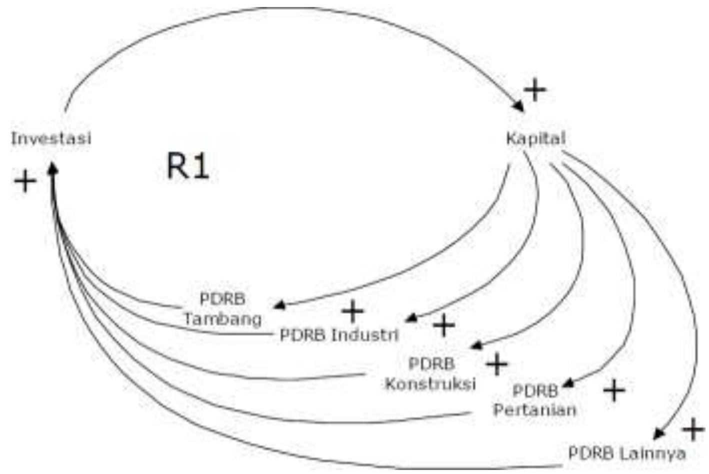
Sedangkan pada CLD Sosial (Gambar 6.1b), fokus pada mekanisme sistem pembangunan manusia, serta aspek demografi dan isu sosial khususnya kemiskinan yang sebagian besar penduduk miskin tersebit berasal dari sektor pertanian. Keterkaitan dengan CLD Ekonomi yaitu melalui variabel PDRB yang memberikan dampak pada kemiskinan, lapangan kerja, dan Indeks Pembangunan Manusia.



Gambar 6.1b. CLD Sosial

Sub model ekonomi

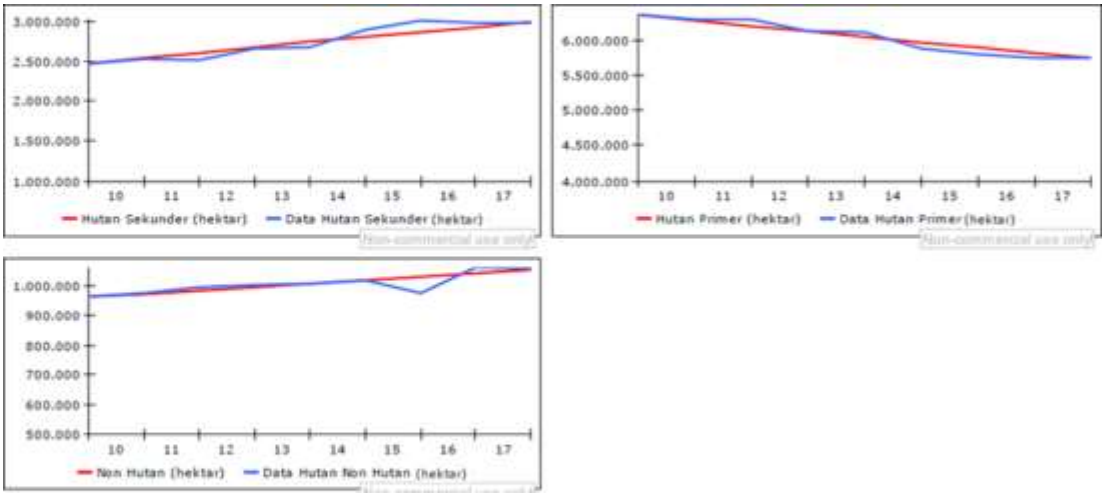
CLD Ekonomi (Gambar 6.1c) fokus pada siklus PDRB dan investasi yang terjadi dalam proses pembangunan di Provinsi Papua Barat. Demikian juga dengan implikasi pada sektor-sektor unggulannya, seperti pertambangan, industri, konstruksi, dan perikanan. Namun sektor penting lainnya, khususnya berkaitan dengan emisi gas rumah kaca adalah sektor kehutanan dan pertanian (diluar perikanan). Perubahan kontribusi sektor berdampak pada perubahan pola emisi, khususnya pada emisi dari dua sektor NDC utama, yaitu energi dan kehutanan. Selain itu siklus PDRB dan investasi juga berkaitan dengan produktivitas yang dipengaruhi oleh dinamika Indeks Pembangunan Manusia. Perlambatan pada pembangunan ekonomi akan menjadi hambatan pembangunan sumberdaya manusia, sebaliknya pembangunan sumber daya manusia menjadi factor penentu produktivitas yang mempengaruhi nilai *Capita Output Ratio* (COR) pada tingkat provinsi.



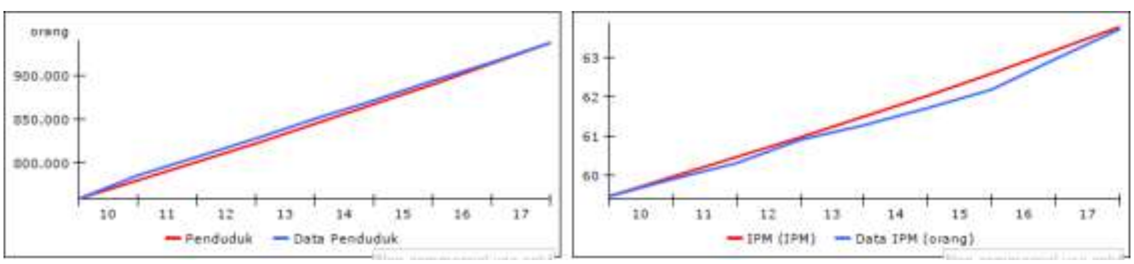
Gambar 6.1c. CLD Ekonomi

4.7 Model Validasi Visual

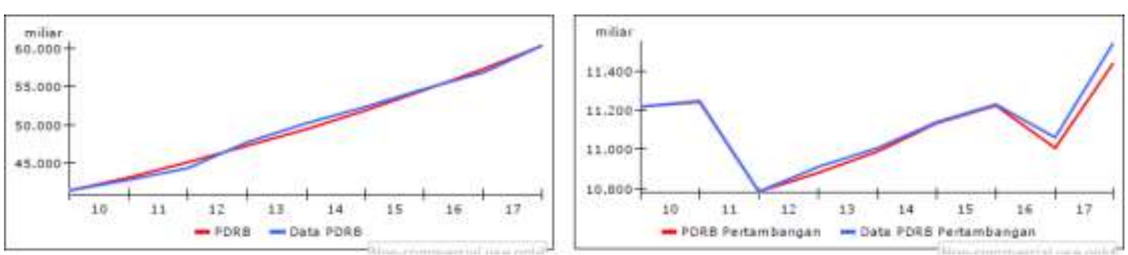
Berdasarkan hasil simulasi Model Implementasi NDC Provinsi Papua dan data referensi 2010- 2018 yang telah dimiliki, dilakukan validasi visual. Hasilnya menunjukkan adanya perilaku sistem (*system behavior*) yang sama. berikut ditampilkan hasil validasi visual untuk masing-masing Sub Model Lingkungan, Sosial, dan Ekonomi:



Gambar 7.1a. Validasi Visual Sub-Model Lingkungan



Gambar 7.1b. Validasi Visual Sub-Model Sosial



Gambar 7.1c. Validasi Visual Sub-Model Ekonomi

Validasi Statistik:

Validasi Statistik dilakukan dengan menggunakan nilai *Absolute Mean Error* (AME) dengan rumus sebagai berikut:

$$AME = |S-R|/R$$

S = nilai rata-rata hasil simulasi R = nilai rata-rata data referensi Model valid jika nilai AME < 0,3

Berdasarkan rumus tersebut, pada Tabel 7 berikut ini disampaikan hasil validasi statistik untuk beberapa variabel yang meliputi Hutan Sekunder, Indeks Pembangunan Manusia, dan PDRB Pertambangan.

Tabel 7. Nilai *Absolute Mean Error* (AME) Model Implementasi NDC Provinsi Papua Barat

Tahun	Hutan Sekunder (hektar)		IPM		PDRB Pertambangan (Rp x 1 miliar)	
	Simulasi	Data	Simulasi	Data	Simulasi	Data
2010	2.468.577	2.468.577	59,47	59,47	11.219	11.220
2011	2.538.575	2.528.171	59,89	59,90	11.227	11.248
2012	2.607.105	2.511.324	60,33	60,30	10.757	10.790
2013	2.674.155	2.658.311	60,76	60,91	10.818	10.913
2014	2.739.699	2.668.486	61,23	61,28	10.913	11.009
2015	2.804.878	2.895.731	61,73	61,73	11.049	11.143
2016	2.867.653	3.011.747	62,25	62,21	11.129	11.231
2017	2.928.117	2.985.362	62,79	62,99	11.898	11.061
2018	2.989.251	2.987.614	63,36	63,74	11.304	11.541
Rata-Rata	2.735.334	2.746.147	61,31	61,39	10.146	11.129
	S	**R**	**S**	**R**	**S**	**R**
AME	**0,0039**		**0,0013**		**0,0016**	

Hasil validasi menunjukkan nilai AME berturut-turut yaitu 0,0039 untuk variabel Hutan Sekunder, 0,0013 untuk variabel IPM dan variabel PDRB Pertambangan memiliki nilai 0,0016. Semuanya nilai AME berada dibawah 0,3 yang berarti model dapat dinyatakan valid.

Asumsi Permodelan:

Pada asumsi aspek lingkungan, secara umum didasarkan pada *time series* data yang diperoleh di provinsi, seperti angka regenerasi dan reforestasi, serta pendekatan nasional, khususnya terkait intensitas emisi sektor NDC. Faktor emisi berbagai kelas pernutupan lahan disederhanakan menjadi 3 kelas, yaitu hutan primer hutan sekunder, dan non hutan, dengan mempertimbangkan dominasi masing-masing tutupan lahan. Selain itu juga dilakukan penyederhanaan terkait angka erosi kedalam 2 kelas, yaitu untuk ekosistem hutan dan non-hutan. Asumsi aspek sosial dan ekonomi berdasarkan pada kondisi umum provinsi maupun nasional, selain itu juga untuk penyederhanaan nilai konstanta karena keterbatasan data yang tersedia.

Beberapa asumsi dan variabel yang diasumsikan konstan dalam Draft Model Implementasi NDC Provinsi Papua yaitu sebagai berikut.

Asumsi Sub Model Lingkungan

1. Angka regenerasi dari hutan sekunder menjadi hutan primer sebesar 0%/tahun dari luas hutan sekunder.
2. Reforestasi buatan dan alami areal non hutan menjadi hutan sekunder sebesar 1%/tahun dari luas areal non hutan
3. Emisi Energi per PDRB sebesar 300,06 ton CO2 eq/Rp. 1 miliar PDRB Sektor Energi
4. Emisi Sampah per PDRB sebesar 12,12 ton CO2 eq/Rp. 1 miliar PDRB
5. Emisi Industri per PDRB sebesar 29,41 ton CO2 eq/Rp. 1 miliar PDRB Sektor Industri
6. Emisi Pertanian per PDRB sebesar 101,69 ton CO2 eq/Rp. 1 miliar PDRB Sektor Pertanian
7. Rata-rata Stok Karbon berbagai jenis Hutan Primer = 285,49 ton CO2 eq/hektar
8. Rata-rata Stok Karbon berbagai jenis Hutan Sekunder = 222,97 ton CO2 eq/hektar
9. Rata-rata Stok Karbon berbagai jenis tutupan lahan non hutan = 121,31 ton CO2 eq/hektar
10. Stok Sumber daya Alam untuk sektor pertambangan dan industri berbasis migas tersedia sampai dengan tahun 2040
11. Erosi potensial ekosistem hutan 11,45 ton/hektar/tahun
12. Erosi potensial ekosistem non hutan 184,65 ton/hektar/tahun
13. Erosi yang dapat ditoleransi 30 ton/hektar/tahun
14. Persentase lahan pertanian terhadap luas total lahan non hutan 56%
15. Angka luas lahan minimum per orang petani 0,76 hektar

Asumsi Sub Model Sosial

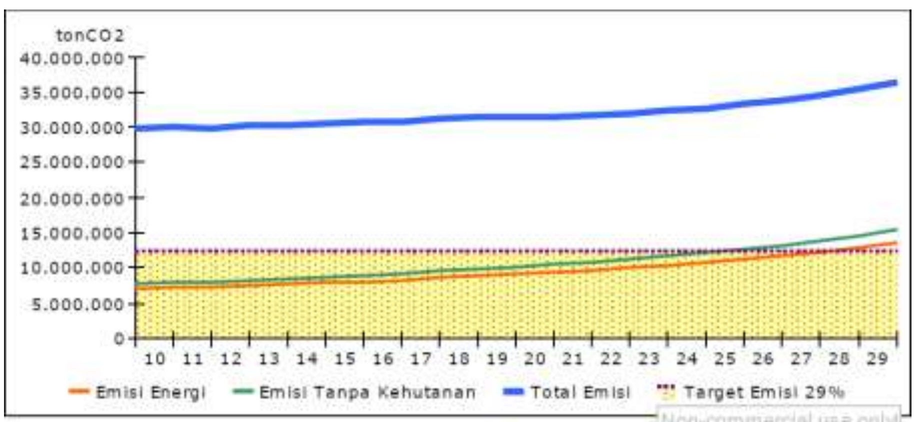
16. Investasi pembangunan sumber daya manusia berasal dari sektor jasa pendidikan, dan jasa kesehatan dan sosial dan dari sektor lain
17. Matapencaharian petani konstan 33,79% mulai tahun 2018
18. Rasio jumlah petani dengan matapencaharian sektor pertanian 65,35%
19. Jumlah investasi pembangunan sumber daya manusia berasal dari sektor lain maksimal sebesar 250% dari Jumlah PDRB sektor jasa pendidikan, dan jasa kesehatan dan sosial setara dengan

Asumsi Sub Model Ekonomi

1) Rata-rata *Capital Output Ratio* (COR) Nasional sebesar 5
2) Rata-rata *Capital Output Ratio* (COR) Nasional untuk sektor pertanian sebesar 4
3) Rata-rata *Capital Output Ratio* (COR) Nasional untuk sektor non pertanian sebesar 6
4) Nilai IPM Provinsi menjadi faktor koreksi nilai COR Provinsi
5) Alokasi investasi sektoral proporsional dengan persentase PDRB sektoral

5 Prediksi Emisi *Business as Usual* (BAU) 2010-2030

Hasil prediksi (gambar 8.1) kondisi *business as usual* (BAU) atau tanpa intervensi sampai dengan tahun 2030 menunjukkan total emisi di Provinsi Papua Barat masih terus mengalami peningkatan. Terlihat bahwa emisi dari sektor kehutanan sangat mendominasi, lebih dari 50% emisi berasal dari degradasi dan deforestasi. Padahal dari aspek ekonomi, kontribusi sektor kehutanan selain relatif rendah, bahkan menunjukkan kecenderungan menurun. Berbeda dengan kondisi nasional, emisi di Provinsi Papua Barat pada periode 2020-2030 masih didominasi oleh emisi sektor kehutanan. Sektor energi memberikan konstribusi yang signifikan di Provinsi Papua Barat, namun menjadi sumber emisi yang relatif lebih kecil dibandingkan sektor kehutanan.



Gambar 8.1. Prediksi Total Emisi Provinsi Papua Barat dan Target Reduksi 29% pada Tahun 2030

Berdasarkan pada target NDC Nasional pada tahun 2030 untuk skenario kemampuan sendiri atau reduksi 29%, pada tahun 2030 total emisi nasional maksimal yaitu 2,034 Giga ton CO_2 eq. Dengan prediksi PDB Nasional (ADHK tahun 2010) pada tahun 2030 yaitu mencapai Rp. 19.652 triliun, maka menggunakan pendekatan emisi per PDB, jumlah maksimal emisi adalah 103,5 ton CO_2 eq/miliar PDB. Selanjutnya dengan prediksi PDRB Provinsi Papua Barat pada tahun 2030, diperoleh emisi maksimal untuk Provinsi Papua Barat yaitu 12.499.212 ton CO_2 eq. Total emisi Provinsi Papua Barat diprediksikan mencapai 38.830.345 ton CO_2 eq (Gambar 7.1), jika tanpa sektor kehutanan, emisi pada tahun 2030 mencapai 16.561.949 ton CO_2 eq yang didominasi dari sektor energi sebesar 14.386.253 ton CO_2 eq. Sedangkan untuk skenario reduksi emisi 38% diperoleh emisi maksimal untuk Provinsi Papua Barat yaitu 10.981.363 ton CO_2 eq (Gambar 8.2).

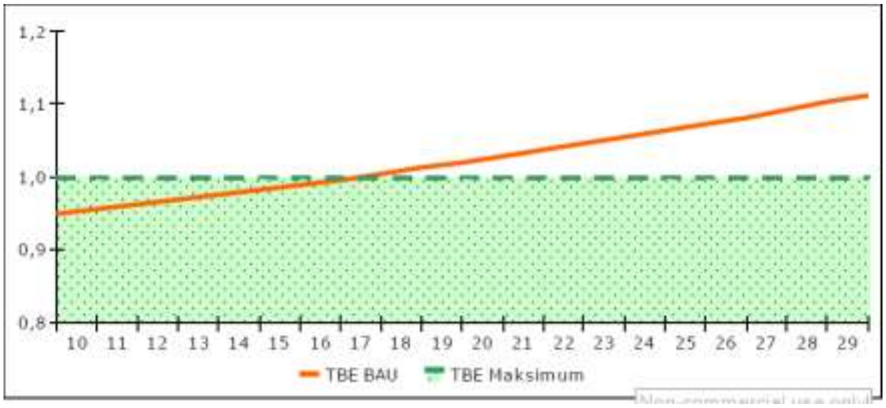
Gambar 8.2. Prediksi Total Emisi Provinsi Papua Barat dan Target Reduksi 38% pada Tahun 2030

Apabila target NDC Indonesia diturunkan dengan pendekatan ekonomi (emisi/PDRB) untuk NDC Subnasional, maka target reduksi emisi Provinsi Papua Barat menjadi 68% dengan kemampuan sendiri untuk menjaga agar emisi tidak melampaui 12.499.212 ton CO_2 eq pada tahun 2030. Sedangkan berdasarkan skenario reduksi emisi dengan kemitraan internasional (reduksi 38%), Provinsi Papua Barat harus memiliki target reduksi 72% dengan kemitraan internasional.

5.1 Skenario NDC Subnasional Berbasiskan Konservasi Ekosistem Hutan

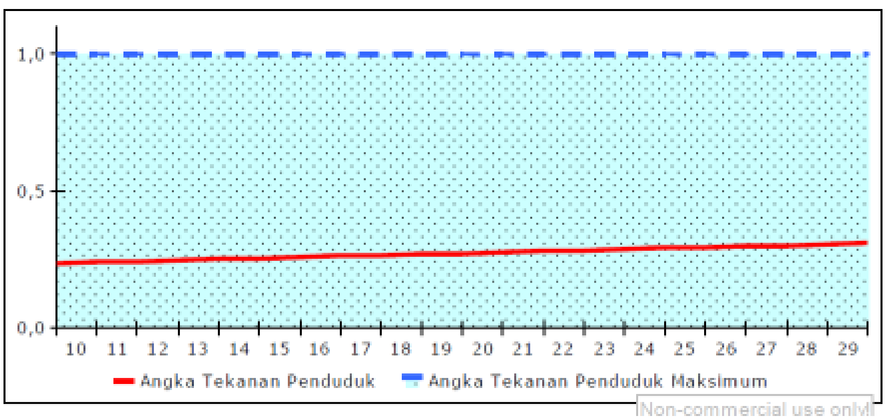
Terdapat dua *threshold* penting pada aspek lingkungan yang dapat digunakan sebagai dasar untuk penetapan target NDC Provinsi Papua Barat, yaitu (i) Luas Hutan berdasarkan pendekatan Tingkat Bahaya Erosi (TBE), dan (ii) kecukupan lahan pertanian berdasarkan pendekatan tekanan penduduk.

Berdasarkan prediksi kondisi *Business as Usual* (BAU), nilai TBE melampaui angka 1 khususnya mulai tahun 2018 (berarti tidak dapat diterima, karena batas maksimum nilai TBE untuk sistem hidrologi ekosistem yang sehat yaitu 1), seperti terlihat pada Gambar 9.1. Tentu saja, selain aspek karbon, implementasi NDC juga perlu mempertimbangkan aspek TBE sebagai salah satu indicator penting ekosistem Daerah Aliran Sungai (DAS)



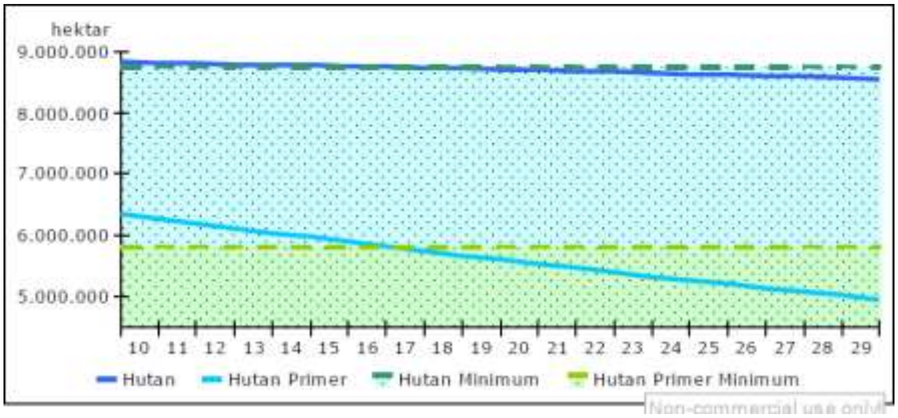
Gambar 9.1. Rata-Rata Tingkat Bahaya Erosi Provinsi Papua Barat 2010-2030

Pada aspek kecukupan lahan pertanian, berdasarkan hasil prediksi *Business as Usual* (BAU) sampai dengan 2030 diketahui angka tekanan lahan masih berada jauh dibawah nilai 1 (Gambar 9.2), artinya ketersediaan lahan non hutan, khususnya lahan pertanian masih mencukupi untuk memenuhi kesejahteraan petani. Sehingga, pembukaan lahan sampai dengan tahun 2030 tidak diperlukan.



Gambar 9.2. Angka Tekanan Penduduk Terhadap Lahan di Provinsi Papua Barat 2010-2030

Mempertimbangkan dua indikator aspek lingkungan di atas, yaitu TBE dan Tekanan Penduduk, dapat ditetapkan luas hutan minimal di Provinsi Papua Barat yaitu seluas 8.750.000 hektar dengan luas hutan primer minimal 5.820.000 hektar. Selanjutnya luas hutan total dan luas hutan primer minimal menjadi dasar penetapan target NDC Provinsi Papua. Dalam draft final ini, *threshold* emisi berbasiskan konsep karbon netral belum diperhitungkan untuk menjadi dasar formulasi NDC Provinsi Papua.



Gambar 9.3. Luas Hutan dan Luas Hutan Primer Minimal di Provinsi Papua Barat

Selanjutnya, untuk mencapai luas hutan minimum, skenario intervensi dilakukan dapat dilihat pada Tabel sebagai berikut.

Tabel 8 Skenario Konservasi Implementasi NDC Provinsi Papua Barat

Skenario	Intervensi	Kondisi Tahun 2030		
		Lingkungan	Sosial	Ekonomi
BAU	Tidak ada	Luas Hutan < threshold TBE > 1 Tekanan Penduduk < 1 Emisi = 36,3 mega ton	Kemiskinan = 10,75% IPM = 75,19	PDRB = 151,8 Triliun
Skenario 1	Lingkungan: 1. Moratorium Kehutanan dan Konversi Hutan 2. Restorasi Hutan Primer	Luas Hutan > *threshold* Luas Hutan primer meningkat namun masih < *threshold* TBE < 1 Tekanan Penduduk < 1 Reduksi Emisi: 69% (euivalen dengan komitmen 29% NDC Nasional)	Kemiskinan meningkat menjadi di 12,68% IPM terkoreksi menjadi = 74,52%	Konstraksi PDRB minus (-) 4% menjadi 146,0 Triliun

Keterangan:

1. *Threshold Konservasi luas hutan minimal = 8.750.000 hektar*
2. *Threshold Konservasi luas hutan primer minimal = 5.820.000 hektar*

Skenario Konservasi Ekosistem Hutan dilakukan dengan dua intervensi, yaitu kebijakan moratorium dan restorasi ekosistem hutan primer. Kebijakan moratorium dimaksudkan mengentikan seluruh kegiatan usaha kehutanan dan perkebunan yang mengakibatkan degradasi dan deforestasi, yang efektif dilaksanakan secara bertahan dalam waktu 2 tahun, yaitu tahun 2022 dan 2023. Sedangkan restorasi ekosistem hutan alam dilakukan dengan melakukan percepatan regerasi alami melalui *enrichment planting* maupun teknik restorasi lainnya dari hutan sekunder menjadi hutan primer pada laju restorasi sebesar 0,02% per tahun.

Melalui intervensi tersebut, pada tahun 2030 emisi Provinsi Papua Barat dapat berkurang menjadi
12.222.472 ton CO2 eq atau terjadi reduksi 69% dari kondisi *business as usual* (BAU) sebesar 38.830.345 ton CO2 eq. Sedangkan hutan Provinsi Papua Barat dapat terjaga dengan luas 8.777.239 hektar, lebih luas dibandingkan syarat minimum 8.750.000 hektar.

Berdasarkan Skenario Konservasi Ekosistem Hutan untuk Implementasi NDC Provinsi Papua Barat, diketahui bahwa terdapat dampak sosial dan ekonomi (Tabel 8). Pada aspek sosial, nilai Indeks Pembangunan Manusia (IPM) yang diprediksikan mencapai 75,19 pada tahun 2030 akan terkoreksi lebih rendah menjadi 74,52. Selain itu, angka kemiskinan dengan kondisi BAU pada tahun 2030 akan berada pada angka 10,75%, ternyata dengan Skenario Konservasi diprediksikan akan terkoreksi lebih tinggi menjadi 12,68%. Tentu saja kondisi ini tidak dapat diterima, karena pembangunan di Provinsi Papua Barat yang saat ini sudah tertinggal akan terhambat dengan implikasi penurunan angka IPM dan meningkatnya angka kemiskinan di tahun 2030 sebagai dampak skenario Konservasi.

Demikian juga pada aspek ekonomi, diprediksikan dalam kondisi BAU, PDRB ADHK (Atas Dasar Harga Konstan 2010) mencapai 146,0 triliun, namun dengan Skenario Konservasi berdampak negatif pada ekonomi, yaitu PDRB terkoreksi sebesar minus (-) 4% dibandingkan kondisi BAU. Kondisi ini tentu tidak diharapkan, karena sebaliknya konservasi ekosistem hutan pada saat yang bersamaan diharapkan mampu meningkatkan kesejahteraan masyarakat Provinsi Papua Barat. Oleh karena itu dibutuhkan skenario yang lebih komprehensif.

5.2 Skenario NDC Subnasional Berbasiskan Pembangunan Berkelanjutan

Seperti telah diuraikan pada Skenario Konservasi, terdapat dampak sosial dan ekonomi. Pada aspek sosial, nilai Indeks Pembangunan Manusia diprediksikan terkoreksi lebih rendah, juga berdampak negatif pada ekonomi, yaitu PDRB terkoreksi sebesar minus dibandingkan kondisi BAU. Selanjutnya dikembangkan Skenario yang lebih komprehensif, yaitu Skenario Pembangunan Berkelanjutan. Dalam skenario NDC subnasional berbasiskan pembangunan berkelanjutan, selain tetap menggunakan skenario konservasi ekosistem hutan, yang terdiri atas intervensi kebijakan moratorium dan restorasi hutan primer, ditambahkan intervensi lainnya, yaitu intervensi pada aspek ekonomi.

Pada intervensi ekonomi dilakukan pengembangan sektor pertanian, khususnya melalui intensifikasi pertanian, serta intervensi lainnya yaitu pengembangan sektor perekonomian non unggulan. Intervensi pengembangan sektor pertanian yaitu melalui intensifikasi pertanian dengan pertumbuhan program pada tingkat 10% per tahun. Sedangkan pengembangan sektor perekonomian non unggulan dengan meningkatkan pertumbuhan ekonomi sektor non unggulan dari 4,52% menjadi 5,52% atau bertambah 1% (Tabel 9).

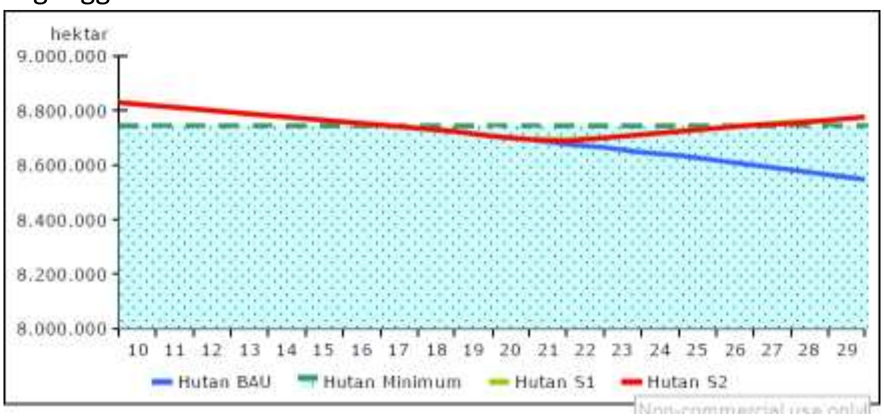
Tabel 9. Skenario Pembangunan Berkelanjutan Implementasi NDC Provinsi Papua Barat

Skenario	Intervensi	Kondisi Tahun 2030		
		Lingkungan	Sosial	Ekonomi
BAU	Tidak ada	Luas Hutan < threshold TBE > 1 Tekanan Penduduk < 1 Emisi = 36,3 mega ton	Kemiskinan = 10,75% IPM = 75,19	PDRB = 151,8Triliun
Skenario 1: Konservasi Ekosistem Hutan	Lingkungan: 1. Moratorium Kehutanan dan Konversi Hutan 2. Restorasi Hutan Primer	Luas Hutan > *threshold* Luas Hutan primer meningkat namun masih < *threshold* TBE < 1 Tekanan Penduduk < 1 **Reduksi Emisi: 69%**	Kemiskinan meningkat menjadi 12,68% IPM terkoreksi menjadi = 74,52%	Konstraksi PDRB minus (-) 4% menjadi 146,0 Triliun
Skenario 2: Pembangunan Berkelanjutan	Lingkungan: 1. Moratorium Kehutanan dan Konversi Hutan 2. Restorasi Hutan Primer Ekonomi: 1. Pengembangan sektor pertanian (intensifikasi) 2. Pengembangan Sektor Non Unggulan	Luas Hutan > *threshold* Luas Hutan primer meningkat namun masih < *threshold* TBE < 1 Tekanan Penduduk < 1 **Reduksi Emisi: 64%**	Kemiskinan menurun (-) menjadi 10,26% IPM meningkat (+) menjadi = 76,33%	PDRB meningkat (+) 15% menjadi 174,5 Triliun

Keterangan:

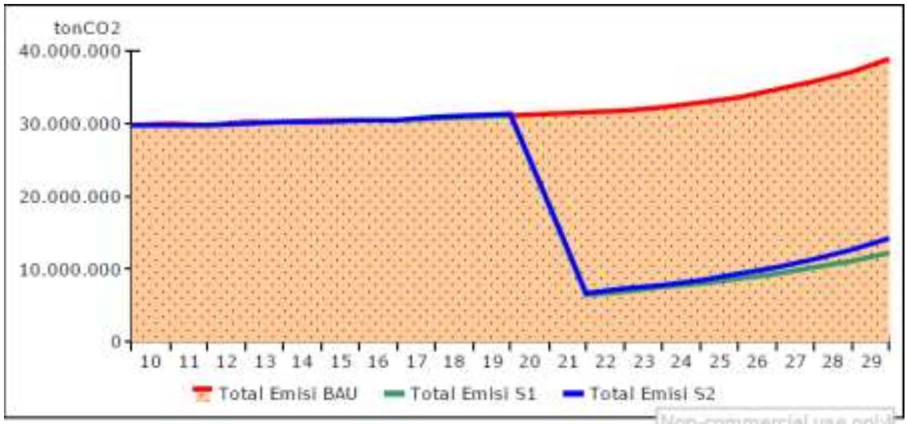
- *Threshold Konservasi luas hutan minimal = 8.750.000 hektar*
- *Threshold Konservasi luas hutan primer minimal = 5.820.000 hektar*

Berdasarkan Skenario Pembangunan Berkelanjutan untuk implementasi NDC Provinsi Papua Barat, diketahui bahwa *threshold* luas hutan minimal dapat tercapai pada tahun 2030 yaitu seluas 8.776.670 hektar. Kondisi ini tidak berbeda dengan Skenario Konservasi, namun keduanya berada dalam kondisi dapat memenuhi *threshold* luas hutan minimal di Provinsi Papua Barat, sedangkan dalam kondisi BAU luas hutan di Provinsi Papua Barat yaitu 8.548.215 hektar, atau berada dibawah *threshold* (Gambar 10.1). Tentu saja karena penetapan luas hutan minimal berdasarkan pada Tingkat Bahaya Erosi dan Tekanan Penduduk, dengan demikian dalam kondisi BAU, Tingkat Bahaya Erosi melampaui angka 1, atau sistem hidrologis di DAS secara umum terganggu.



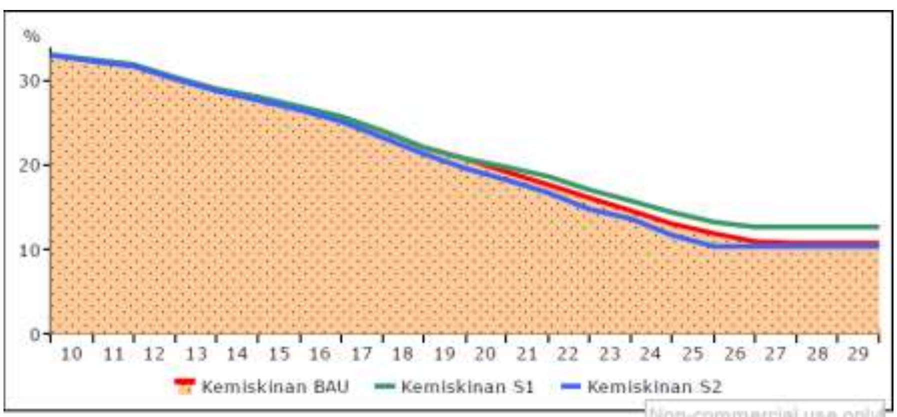
Gambar 10.1. Skenario Prediksi Luas Hutan Implementasi NDC di Provinsi Papua

Skenario moratorium, atau penghentian seluruh kegiatan usaha kehutanan dan perkebunan yang mengakibatkan degradasi dan deforestasi efektif dilaksanakan secara bertahap dalam waktu 2 tahun, yaitu tahun 2022 dan 2023, berdampak drastis pada emisi khususnya dari sektor kehutanan. Diprediksikan dalam kondisi BAU total emisi pada tahun 2030 mencapai 38,8 mega ton CO_2 ekuivalen, melalui Skenario Konservasi dalam implementasi NDC, emisi berkurang menjadi 12,2 mega ton CO_2 ekuivalen. Sedangkan dengan Skenario Pembangunan Berkelanjutan dalam implementasi NDC akan mencapai 14,1 mega ton CO_2 ekuivalen pada tahun 2030 (Gambar 10.2).



Gambar 10.2. Skenario Prediksi Emisi Implementasi NDC di Provinsi Papua

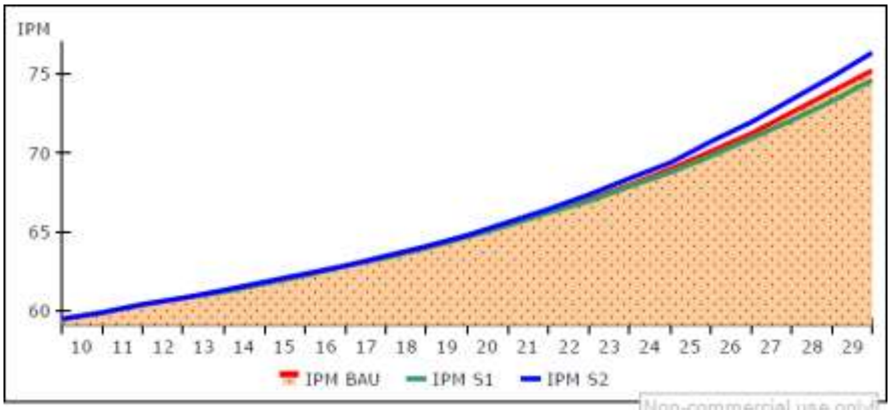
Skenario Konservasi untuk Implementasi NDC Provinsi Papua Barat berdampak pada aspek sosial, khususnya upaya pengentasan kemiskinan dan pembangunan sumber daya manusianya. Diprediksikan pada tahun 2030, dengan Skenario Konservasi, angka kemiskinan berada pada tingkat 12,68%, lebih tinggi dari kondisi BAU. Artinya Skenario Konservasi tidak mendukung upaya pengentasan kemiskinan. Dalam Skenario Pembangunan Berkelanjutan, diprediksikan angka kemiskinan pada tahun 2030 mencapai 10,29%, tidak hanya lebih rendah dari angka kemiskinan pada Skenario Konservasi, namun juga lebih rendah dari angka kemiskinan pada Skenario BAU yaitu 10,75% (Gambar 10.3).



Gambar 10.3 Skenario Prediksi Angka Kemiskinan Implementasi NDC di Provinsi Papua

Menggunakan indikator Indeks Pembangunan Manusia (IPM), diprediksikan pada tahun 2030 nilai IPM di Provinsi Papua Barat dalam kondisi *business as usual* (BAU) akan mencapai 75,19. Berdasarkan Skenario Konservasi tingkat IPM yang akan dicapai pada tahun 2030 sedikit lebih rendah yaitu 74,52. Penurunan IPM ini disebabkan intervensi moratorium menyebabkan terkoreksinya PDRB pada tahun 2030 menjadi lebih rendah dari kondisi BAU sebesar 152,8 triliun menjadi 146,0 triliun. Sedangkan melalui Skenario Pembangunan Berkelanjutan nilai

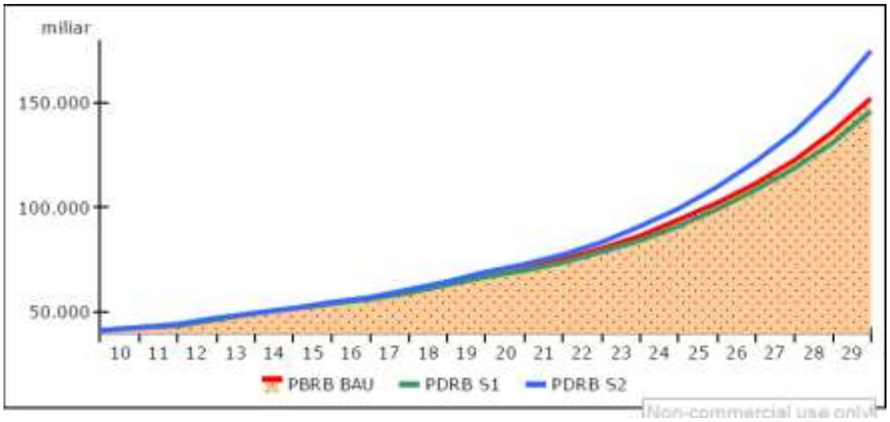
IPM Provinsi Papua Barat akan mencapai 76,25. Angka tersebut juga tidak hanya lebih tinggi dari Skenario Konservasi, namun juga lebih tinggi dibandingkan hasil prediksi kondisi BAU (Gambar 10.4). Tentu hal ini disebabkan meningkatkan PDRB pada tahun 2030 pada skenario ini dengan adanya intervensi pengembangan intensifikasi pertanian yang menjadi kantong kemiskinan dan pengembangan sektor ekonomi non unggulan, seperti sektor pariwisata yang potensial dikembangkan di Provinsi Papua Barat



Gambar 10.4. Skenario Prediksi Indeks Pembangunan Manusia Implementasi NDC di Provinsi Papua

Pada aspek ekonomi, hasil prediksi Skenario Pembangunan Berkelanjutan menunjukkan capaian PDRB Provinsi Papua Barat pada tahun 2030 lebih tinggi dari kondisi BAU dan prediksi Skenario Konservasi untuk implementasi NDC. Faktor utama yang mendorong kondisi perekonomian di tahun 2030 lebih baik, karena intervensi ekonomi sektor pertanian yaitu dengan pengembangan intensifikasi di sektor pertanian serta pengembangan pertumbuhan ekonomi pada sektor yang selama ini tidak menjadi unggulan.

Pada tahun 2030 diprediksikan PDRB Provinsi Papua Barat dengan menerapkan Skenario Pembangunan Berkelanjutan yaitu mencapai 174,5 triliun (ADHK 2010), lebih tinggi 15% dibandingkan dengan prediksi PDRB dengan kondisi BAU yaitu 151,8 triliun. Jika dibandingkan dengan Skenario Konservasi dengan jumlah PDRB sebesar 146,0 triliun, Skenario Pembangunan Berkelanjutan meningkat 19,5%.



Gambar 10.5. Skenario Prediksi PDRB Implementasi NDC di Provinsi Papua

Mempertimbangkan Skenario Konservasi dan Skenario Pembangunan Berkelanjutan untuk implementasi NDC di Provinsi Papua Barat, jelas menunjukkan bahwa hasil prediksi Skenario Pembangunan Berkelanjutan adalah lebih baik pada aspek lingkungan, sosial, maupun ekonomi. Selanjutnya konsep implementasi NDC Provinsi Papua Barat perlu menerapkan Skenario Pembangunan Berkelanjutan.

6 Rekomendasi NDC Subnasional Provinsi Papua Barat

Berdasarkan hasil analisis menggunakan metode *system dynamics*, dengan membandingkan skenario kondisi *business as usual* (BAU), Skenario Konservasi Ekosistem Hutan, dan Skenario Pembangunan Berkelanjutan diketahui bahwa Skenario Pembangunan Berkelanjutan adalah skenario terbaik. Secara rinci rekomendasi NDC Subnasional Provinsi Papua Barat ditampilkan pada Tabel 10. Total reduksi emisi Provinsi Papua Barat pada tahun 2030 sebesar 64% atau 24,76 mega ton CO_2 ekuivalen.

Tabel 10. Rekomendasi NDC Subnasional Provinsi Papua Barat.

No	Sektor NDC	Emisi 2020	Emisi BAU 2030	Emisi NDC 2030	Reduksi Emisi 2030	Persentase Reduksi Emisi 2030
		Kilo Ton CO2e	Kilo Ton CO2e	Kilo Ton CO2e	Kilo Ton CO2e	(%)
1	Energi	9.018,25	14.386,25	15.206,87	-820,62*)	-6%
2	Sampah	809,66	1.840,85	2.116,18	-275,33*)	-15%
3	IPPU	60,85	110,66	116,98	-6,32*)	-6%
4	Pertanian	162,90	224,18	558,76	-334,58*)	-149%
5	Kehutanan	21.103,39	22.268,40	- 3.930,40	26.198,80*)	118%
Total		**31.155,06**	**38.830,35**	**14.068,38**	**24.761,97**	**64%**

Keterangan: *) tidak ada reduksi, untuk menjaga kesejahteraan dan ketahanan iklim masyarakat Provinsi Papua Barat, serta menjaga modalitas ekonomi untuk transisi menuju pembangunan ekonomi wilayah yang berkelanjutan.

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III. Prosiding Internasional Hasil TASCA TAHAP II

Scenario for West Papua contribution for NDC from forestry sector

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Abstract. West Papua's tropical forests are one of the mega biodiversity in the Sahul Shelf ecoregion. The increasing economic growth has a déterrent impact on deforestation and forest degradation with the rate increased by 1.29% per year (2010-2018). Meanwhile, economic growth in Gross Regional Domestic Product (GRDP) reached 4.87% per year. This study aims to simulate carbon management from the forestry sector in West Papua into the long-term low-carbon sustainable development. This research uses a dynamic system method through Stock Flow Diagram (SDF) stage and model validation. The results showed that the forestry GRDP and emission based on the CM1 and CM2 scenarios calculated using emission reduction of 69.61% and 91.04% were determined by 0.28 and 0.09 times from BAU. The total GRDP and forestry GRDP decreased by 5.19% (CM1) and 6.59% (CM2) and 71.57% (CM1) and 90.93% (CM2). Under this scenario, West Papua could maintain a forest cover of more than 85%. The study concludes that the results of the BAU scenario predict forest cover of 70% in 2030. Simulations carried out with CM1 and CM2 reduction in emissions show that the achievement of forestry GRDP, total GRDP, and emissions is lower than BAU.

1. Introduction

Forest holds an essential role in climate mitigation efforts by preserving and adding its carbon sinks and curbing the deforestation rate that drives GHG gas emissions. Following the Paris Agreement, countries submitted their national commitments that reaffirmed the roles of forest and land-use change (LUCF) in climate mitigation. If NDC is fully implemented, it is expected, by 2030, the world will reach a net carbon sink (up to -1.1 ± 0.5 $GtCO_2^{e-1}$ per year) and provide a quarter of the country's planned emission reductions [1]. If countries fail to protect their remaining forest, it will be more difficult to limit the temperature increase to below 1.5°C. Achieve such commitments; many tropical countries opt for reforestation and other forest management options to ensure CO_2 sequestration Forestation and other forest management options to sequester CO_2. Nevertheless, such attempts could face failure should problems related to poverty, social, environmental, and politics are not properly recognized [2].

In Indonesia, the LUCF sector is the main foundation of the NDC emission reduction target, accounted for 63% of the target [3]. Of 189 million ha land in Indonesia, the potential to utilize unproductive land to increase carbon sequestration exists. The current national afforestation/reforestation program remained under the total unproductive land available for mitigation. Indonesia also has provinces with intact forests such as Papua and West Papua that offer NDC opportunities by keeping the forest standing [4].

The islands of Papua and New Guinea are home to the third-largest tropical rainforest globally with a diversity of bird and plant species as in Australia, which is only one-tenth of its land area (Sahul Shelf). Some of the fauna include tree kangaroos and birds of Paradise with various species, while flora consisting of Merbau (*Intisa palembanica*), akway (*Drymis sp*.), Matoa (*Pometia pinnata*), etc. [5]. In the 2018 Manokwari Declaration, West Papua has declared 70% of its territory as a conservation area. Despite such ambitious commitments, it is not easy to achieve, given the need to achieve economic growth. On March 20, 2019, the Regional Representative Council ratified the Sustainable Development Special Regional Regulation (Perdasus) Policy, which formalized the provincial development paradigm. This provides a legal basis for local governments to study and implement development programs in the province. West Papua Province has entered Nationally Determined Contributions (NDCs) to oversee the issue of reducing emissions. The West Papua government has signed an MoU with Bappenas for low-carbon development planning, in which gas emissions are targeted to decrease by 15 percent by 2020. Emission reduction is expected to support the central government's program to reduce GHG emissions by up to 29% with its efforts and 45% with external assistance from 2030 [3].

West Papua Province has 138,385 $km^{2,}$ with a predominantly forest area of 97,239 km^2 [6]. On the environmental aspect, development in West Papua Province has the impact of degradation and deforestation. Statistical data shows a significant increase in forest cover from 2007 to 2018. In 2007, nearly 97% (9,480,338 ha) of West Papua's land area was covered by forest. In 2018, this figure decreased to 8,600,000 ha or around 88% of the province's area [12]. Although the current state of West Papua's forest cover remains above the national minimum threshold of 30%, these changes cannot be ignored. Based on data [7], it is estimated that the primary forest area will reach 6,226,200 ha in 2010 and will continue to be degraded to 5,758,700 ha in 2018 (degradation rate of 1.05% per year). The primary forest conversion has increased secondary forest between the 2010-2018 period from 2,992,200 ha from 2,464,000 ha in 2018. Meanwhile, the secondary forest conversion into shrubs or non-forest areas reached 2.41% per year. This has increased the non-forest areas to 1,059,347 million hectares.

Forest conversion into secondary and non-forest land is often inevitable with the accelerating economic development efforts at the provincial level. As of January 2020, West Papua is the second poorest province in Indonesia, with 21.51%of its population lives below poverty lines [8]. To improve economic conditions, the West Papua government has developed reliable targets with the Gross Regional Domestic Product (GRDP) for the 2010-2018 period accounting for 4.87% per year at constant prices [9].

It is taking the potential contribution of West Papua province to NDC through LUCF and the region's need to achieve its potential growth into account. This research would like to simulate carbon management from the forestry sector in West Papua into long-term low-carbon sustainable development to increase economic growth. Maintain forest cover up to 70% based on the Manokwari Declaration and reduce GHG emissions by up to 29% by own efforts and 41% with foreign assistance by 2030. Forest management towards low carbon development is one of the concrete instrument solutions in assessing and planning social, economic, and environmental programs towards sustainable development. We hope this study can contribute to the sustainable development discussion in West Papua that allows the province to meet current needs without sacrificing future generations by focusing on the environment's carrying capacity, achieving social justice, economics, and environmental sustainability in West Papua Province.

2. Method

2.1. Concept development

The method used in this research is system dynamics modeling. The data used in West Papua data with the variables shown in Table 1.

Table 1. General variables for forest management modeling [9, 21].

No	Selected Variable	Baseline Value	Unit	Calculation Method
1	Total Goss Regional Domestic Product (GRDP)	41,362 (2010)	Billion	Total GRDP data (BPS Papua Barat 2010-2018)
2	GRDP of the forestry sector	1,361 (2010)	Billion	GRDP of forestry data (BPS Papua Barat 2010-2018)
3	Deforestation and degradation	58,200 (2010)	Ha	Recapitulation of forest and land cover (KLHK 2010-2018)

4	Emission	10,522,475.13 (2010)	$tonCO_2e$	Emission Data x Emission Factor [21]
5	Forest Management	26.30 (CM1) and -18.43 (CM2) (2010)	Percentage	Estimation (1 – Forestry Emission/ Emission Target) x Investment Fraction

Noted: CM1 (reduce emission 69.61% from BAU 2030) and CM2 (reduce emission 91.04% from BAU 2030).

Although West Papua still maintains more than 80% of its primary forest, other economic development conditions significantly affect increasing GHG emissions in West Papua Province [14]. This can be used to declare West Papua's NDC contribution for the national level commitments. The modeling stage consists of drafting, modeling, simulating, and validating the simulation results.

2.2. Modeling

At this stage, Stock Flow Diagrams (SFD) are used in the Powersim 10 Software, which is depicted in a diagram consisting of 2 types of variables, namely stock (level) & flow (rate) inside dynamic systems modeling. The SFD is a more detailed description and paid attention to the effect of time on linkages between variables. Later, each variable showed the accumulated results for a variable level and the variable, which is the activity system rate.

2.3 Simulation and validation of the model

At this stage, Stock Flow Diagrams (SFD) are used in the Powersim 10 Software, which is depicted in a diagram consisting of 2 types of variables, namely stock (level) & flow (rate) inside dynamic systems modeling. The SFD is a more detailed description and paid attention to the effect of time on linkages between variables. Later, each variable showed the accumulated results for a variable level and the variable, which is the activity system rate.

$$AME = (Si - Ai) / Ai \times 100\% \qquad (1)$$

AME is an absolute mean error, A is the actual value, and S is the simulation value. The AME value-based limit to relate to uncontrollable variables in this study is 30% [13].

3. Results and discussion

3.1. Baseline data of forest management (2010-2018) in West Papua

The compilation of a baseline under Business as Usual scenario (BAU) for the preparation of the West Papua Province RAD-GRK for the forestry sector is carried out using the historical-based time-series data (2010-2018) on forest conversion and land use and land-use change (LULUCF) as well as the identified drivers of deforestation and forest degradation in West Papua Province, namely illegal logging; forest fires; and conversion of forest land for other activities such as plantation and agricultural areas, expansion of areas (regencies), mining and settlements. The total value of deforestation and degradation (2010-2018) has almost reached 2 million ha with an annual rate of 200.000 ha (Table 2).

Using the deforestation and degradation data extracted from Regional Action Plan for Greenhouse Gas Reduction in West Papua Province 2013-2020 period [14], the analysis found cumulative emissions from forest conversion, land use, and land-use change (LULUCF) in the 2010-2018 Period of 62,507,052 tonCO_2e as shown in Table 2. A year to year cumulative emissions of West Papua until 2018 continued to increase as calculated using deforestation and degradation data based on historical scenarios based on stock change and gain-loss, a 4x increase from the base year, 2010.

To achieve the emission levels in Table 2, the growth rate of GRDP of West Papua in the period 2010-2018 must reach 4.87% per year. While the growth rate for the GRDP of the forestry sector also increased by 4.95% per year.

Table 2. Forest area, non-forest area, Total GRDP, GRDP of Forestry, Emission (2010-2018) [9].

Year	Primary Forest (Ha)	Secondary Forest (Ha)	Non-forest area (Ha)	Total GRDP (billion Rp)	GRDP of forestry (billion Rp)	Total Emission (tCO_2e)
2010	6,226,200	2,464,000	837,700	41,361.7	1,362.1	24,650,073
2011	6,026,800	2,430,600	837,700	42,867.2	1,423.7	29,580,087
2012	6,024,100	2,413,100	1,219,000	44,423.3	1,541,5	34,311,958
2013	6,127,200	2,660,300	830,900	47,694.2	1,420.2	39,083,828
2014	5,605,300	3,259,200	760,300	50,259.9	1,563.3	43,835,699
2015	5,890,500	2,899,300	834,800	52,346.5	1,663.1	48,587,569

2016	5,806,400	3,015,200	803,,700	54,711.3	1,641.8	53,339,440
2017	5,761,400	2,989,400	873,900	56,906.8	1,700.9	57,923,246
2018	5,758,700	2,992,200	873,900	60,453.6	1,971.9	62,507,052

3.2. Stock flow diagram

At this Stock Flow Diagram (SFD) stage, the modeler can add variables to the explicit models such as capital, investment, and Incremental Capital Output Ratio (ICOR) from forestry and non-forestry sector (Figure 1) and the other variables for reduction emission for 29% (CM1) and 41% (CM2) (Figure 2).

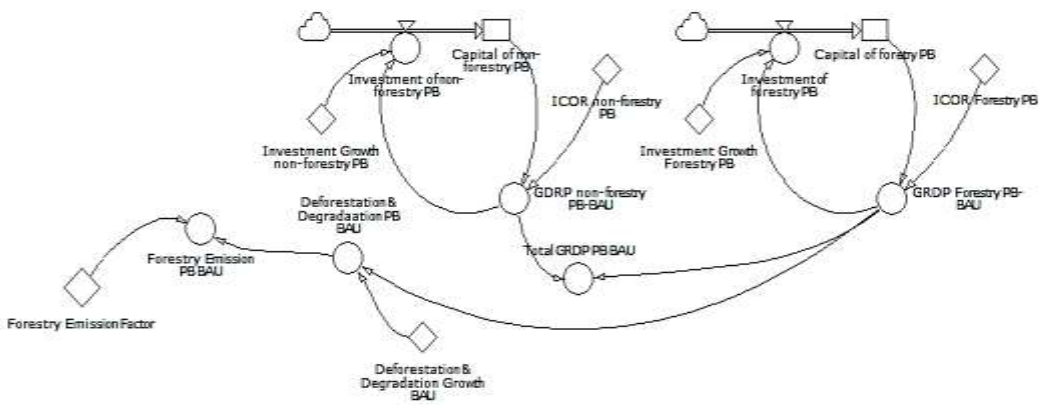

Figure 1. SFD Forest Management in West Papua.

Figure 1 shows that BAU's SFD variables consist of economic factors by considering the GDRP value of forestry originating from ICOR, capital, and investment. Meanwhile, the forestry factor comes from the value of deforestation and degradation data and the GRDP of the forestry sector. Then, emission will be calculated from deforestation and degradation data using Emission Factor.

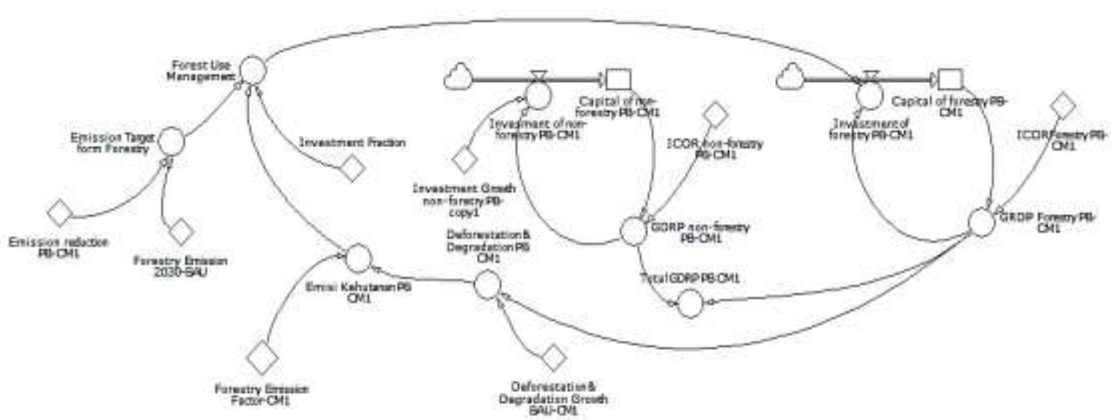

Figure 2. SFD Forest Management Emission Target in West Papua.

Figure 2 represents that the SFD of CMI and CM2 scenario variables require forest use management treatment obtained from the BAU (2030) emission target value, 69.61% (CM1), and 91.04% (CM2) emission reduction from deforestation and degradation and investment fraction.

3.3 Process of simulation

The forest management model is a simplification of the real condition in the field. The following are the assumptions and limitations in the model that can be identified in Table 3.

Table 3. The initial value of simulation and estimation methods [9, 21].

No	Selected Variable	Baseline Value	Unit	Calculation Method
1	Capital of the forestry sector	3,459.78	billion	GRDP of forestry data (BPS 2008-2018) x ICOR forestry sector (Bappeda, 2017)
2	Capital of non-forestry sector	199,626.03	billion	GRDP of non-forestry data (BPS 2008-2018) x ICOR non-forestry sector (Bappeda, 2017)
2	Waste density	169.44	kg/m^3	Secondary data, IPCC (2007)
3	Investment growth from the forestry sector	33.68	%	Investment from forestry data (BPS 2008-2018)
4	Investment growth from the non-forestry sector	26.58	%	Investment from non-forestry data (BPS 2008-2018)
5	Deforestation & degradation growth	129.93	ha/billion	Deforestation & Degradation Data (BPS 2008-2018) / GDRP from forestry sector
6	Forestry Emission Factor	72.33	$tonCO_2e/ha$	Differential stock carbon from the primary and secondary forest (IPCC, 2007)
7	Emission Reduction CM1	69.61	%	Target/BAU (KLHK, 2018) 497 $MtonCO_2e$/714 Mt CO2e
8	Emission Reduction CM2	91.04	%	Target/BAU (KLHK, 2018) 650 $MtonCO_2e$/714 Mt CO_2e
9	Emission 2030 BAU	83,315,054.74	tCO_2e	Data Emission x Emission Factor (IPCC, 2006)

3.4. Validation model

Furthermore, the environmental model is validated using the Absolute Mean Error (AME) value with the following formula: AME = |S-R| / R, where S is the average value of the simulation results. R is the average value of the reference data. The model is valid if the AME value <0.3. Based on this formula, the environmental sector validation can be seen in Table 4.

Table 4. Validation from carbon management.

Years	Deforestation & Degradation		Total GRDP		Forestry GRDP	
	Data	Simulation	Data	Simulation	Data	Simulation
2010	58,200	145,479	41,362	41,205	1,362	1,120
2011	58,200	161,335	42,867	43,467	1,424	1,242
2012	401,500	178,920	44,423	45,856	1,542	1,377
2013	738,400	198,422	47,694	48,380	1,420	1,527
2014	147,600	220,050	50,260	51,047	1,563	1,694
2015	149,200	244,034	52,346	53,866	1,663	1,878
2016	62,900	270,633	54,711	56,845	1,642	2,083
2017	141,000	300,141	56,907	59,995	1,701	2,310
2018	100	332,845	60,454	63,326	1,972	2,562
Average	195,233	227,948	50,114	51,554	1,588	1,755
	S	**R**	**S**	**R**	**S**	**R**
AME	0.1678		0.0287		0.1052	

The validation results in deforestation and degradation areas, Total GRDP and Forestry GRDP, show that the AME value is 0.1678; 0.0287, and 0.1052. This value indicates that the AME value is <0.3, which means that the model is valid.

3.5. Simulation analysis

The forest management simulation model in West Papua is performed with functional intervention from BAU, CM1, and CM2 scenario. Changes in the leverage factor affecting the model were carried out in the CM1 and CM2 scenarios. This aims to find the most effective policies in reducing GHG emissions in the CM1 and CM2 scenarios. (Table 5).

Table 5. Scenario reduce emission from the forestry sector.

No	Scenario	Emission Level	Unit	Estimation Method
1	CM1	25,319,445	tCO_2e	BAU 2030 x 69.61%
2	CM2	7,465,029	tCO_2e	BAU 2030 x 91.04%

Based on the forest management model, deforestation and degradation from the forestry sector of BAU scenario 2030 are still maintaining 70% forest cover. Furthermore, to implement LCD in West Papua, the CM1 scenario can save forest up to 71.57% until 2030 from the BAU scenario or maintaining forest to 84.64%. However, this will decrease the economic value of GRDP from the forestry sector from IDR 8,865.34 billion of BAU 2030 to IDR 2,520.14 billion of CM1 2030 (-71.57%) (Figure 3). Meanwhile, the Total GRDP has reduced by only 5.19% from IDR 122,271 billion (BAU) to IDR 115.926.02 billion (CM1) (Figure 4). We can see the decline of a 0.28 time of BAU scenario for the emission calculation when emissions are reduced to 71.57% from BAU (Figure 5).

The CM2 scenario is based on the emission level with reduced 91.04% emission from the BAU scenario. Calculate the CM2 scenario; forest cover can be maintained up to 86.93% until 2030 from the BAU scenario. This scenario will impact the decline of forestry GRDP of 0.09 times lower than the BAU scenario (Figure 3). At the same time, the Total GRDP has declined by 6.59% from a value of IDR 122,271 billion (BAU) to IDR114,209 billion (CM2) (Figure 4). The same condition for the emission of CM2 scenario is 0.09 times from the BAU scenario (Figure 5).

NDC forestry sector scenario shows that the forestry GRDP is estimated to an unrealistic target; it is necessary to strengthen mitigation action to perform the NDC target. Several studies have also shown difficulties in achieving the 2030 NDC target in the forestry sector. Therefore researchers have provided NDC mitigation input such as the implementation of REDD+, conservation practices, afforestation, reforestation, a moratorium on licensing of new companies and large plantations, and developing another mitigation sector such as green energy, green agriculture, and green transportation. [12,13,14,15].

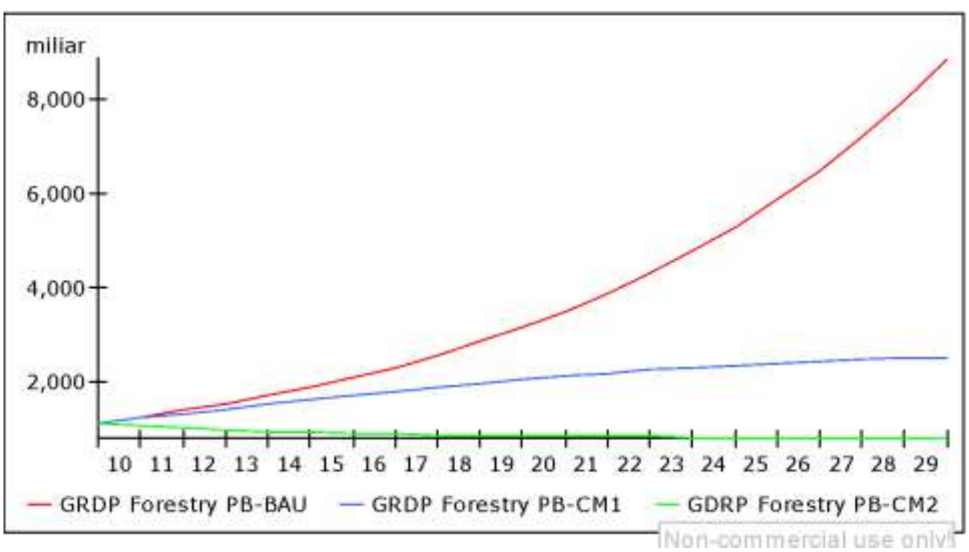

Figure 3. GDRP of forestry sector (BAU, CM1, CM2).

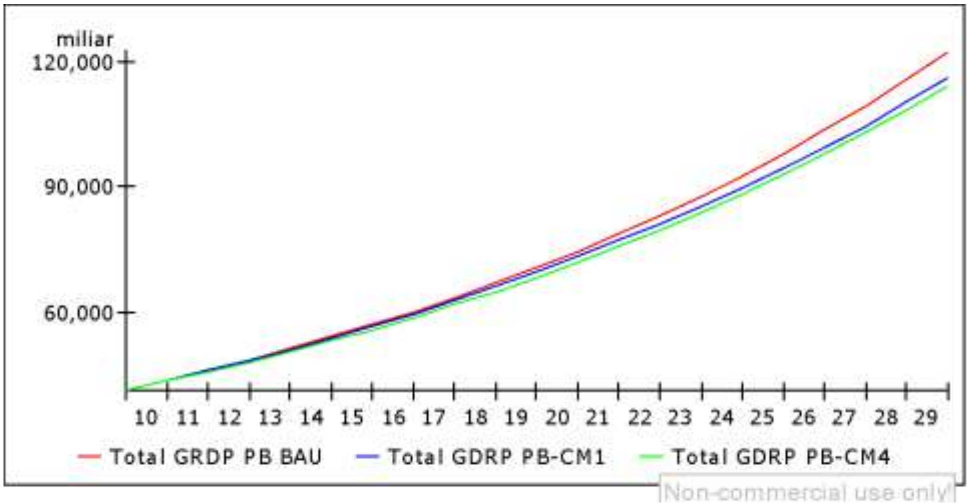

Figure 4. Total GRDP (BAU, CM1, CM2).

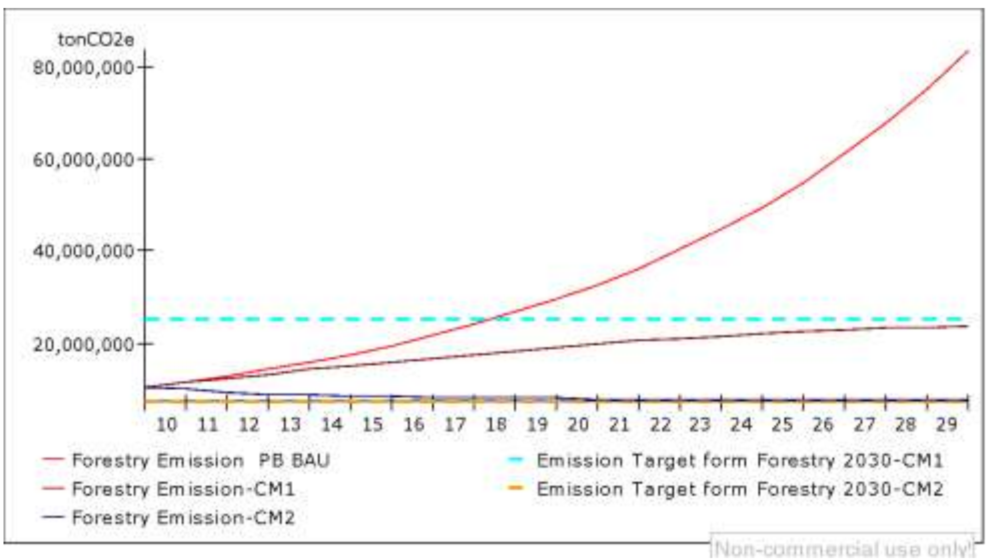

Figure 5. Emission from the forestry sector (BAU, CM1, CM2).

Maintain the economic sector from falling in the CM1 and CM2 scenario, mitigation, and green growth efforts need to be done by considering preserving forests and increasing the welfare of indigenous peoples, as reflected in the Manokwari Declaration increased. Researchers have provided many suggestions and suggestions regarding the green economy so that the economy continues to run well while still paying attention to forest sustainability [16,17,18,19,20]. Based on the experiences and researches, several efforts that have made in West Papua, as the following:

1. Identifying company permits located in forest areas (policy strategy).

2. We are collaborating with Bappenas in implementing the Low Carbon Development Indonesia program at the provincial level (policy strategy).
3. We are promoting downstream industry from non-timber forest products such as nutmeg oil, masohi oil, eucalyptus oil, cacao, coffee, and others (economic strategy).
4. We are developing the economy from environmental services such as the clean water industry and natural tourism (butterflies, primary forest, paradise bird, smart bird, coral reef, white sand and blue sea, and others) (economic strategy).

4. Conclusion

Reducing emission from the forestry sector is needed for the NDC target in West Papua Province. Dynamic system modeling clarifies that the NDC target from the forestry sector faces an extreme economic sector problem. This research modeling exercise showed how West Papua could maintain forest cover to 84,64% (CM1) from BAU by 2030. However, this will come at the expense of the province economic growth as GDRP from the forestry sector sharply decline by 71.57% lower in comparison to BAU. This makes the provincial contribution for NDC from the forestry sector becomes unrealistic. Unless the province is fairly compensated for their performance, such as REDD+ schemes, Until recently, the global carbon market is still relatively low, thus raises pessimism among forest-rich countries on market-based REDD+ financing. At the global level, the difficult negotiation process on Article 6 of the Paris Agreement arranges on carbon market mechanisms and how national-subnational benefit-sharing ring mechanism architecture will add to the complexities. West Papua province requires a unique development approach, given its carbon sequestration potential. Current low carbon development initiatives open up a window of opportunity that allows conservation and development comes hand in hand. The on-going COVID-19 pandemic put the process to halt, and the post recoveries open up bigger calls for building back better. Further research that simulates NDC's provincial contribution is needed by taking more diverse social and economic variables such as health, human development index, education level, and others.

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Towards A Low Carbon Solid Waste Management in West Papua

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Abstract. Solid waste is one of the main contributors to greenhouse gas (GHG) emissions. With an increasing population and Gross Domestic Regional Product (GDRP) of West Papua at 2.65% and 5.2% per annum respectively, solid waste production will also be increased as well as GHG emissions. However, a specific amount of GHG emission in West Papua was yet to be determined due to the unavailability of the numbers of solid waste generation across all districts within West Papua. To measure the aforementioned data, this paper aims to assess solid waste generation by using approach with dynamic model system that involved total population and GDRP across West Papua as the main variables. This paper shows 2 (two) scenarios to simulate the business as usual (BAU) process of existing waste management and proposed scenarios to reduce the GHG emission at convenient level. Based on BAU model, West Papua will produce 3.7 million ton of waste and 1.1 million ton CO_2e in 2030. The proposed scenario suggests that West Papua should manage their waste up to 118.297 ton/year to meet the NDC 29% emission reduction target. These models could be replicated to solve the same issues on different areas.

1 Introduction

Waste is a compulsory by-product of human activities and/or natural processes, which consists of household waste and specific waste. Indonesian act no 18/2018 stipulates that daily activities are the sources of household wastes which exclude feces and specific waste (Act No. 18/2008 of Home Affairs Ministry of Republic Indonesia) [1]. When accumulates, waste will lead to the environmental degradation and various health-related problems [2]

Waste characteristics can vary widely, depending on waste components. What can be considered as solid wastes from human and animal activities are normally solid and regarded as useless by the waste producers [3]. The uniqueness of solid waste from various places or regions and its different types allows different characteristics [4]. The solid waste generally produces greenhouse gas emissions in the form of CH_4 and CO_2. The solid waste burning activity produces CO_2 gas, while open dumping in the landfill causes the organic waste accumulation under anaerobic decomposition and produces CH_4 gas [5]. These gases which are included in greenhouse gases (GHGs) has great potential in global warming. Waste management activities contribute around 4% of greenhouse gases [6]. The existing solid waste disposal site contributes 3-4% of GHG emissions globally [7]. However, appropriate waste management reduces the atmospheric pollutants, odors, and greenhouse gases emission [8]. To conserve local and global environment, a proper waste management is deemed pivotal and should be an integral part for public and environment health.

West Papua province is located in the eastern Indonesia with total area of 567 km^2. In 2010, total population in West Papua was 765,258 people in 2010 but has been increased to 959,617 in 2019 with a population growth rate of 2.65% per year [9]. The increasing population will create unavoidable consequences for increasing volume of waste which could give serious impact for the environment if it is not managed properly. Thus, waste management should be prioritized to reduce the GHG impact on the atmosphere. This is in accordance with Minghua et al. (2009) which stated that solid waste generation at the municipal level grows at the accelerate pace as population growth, increasing influx of urbanization, economic growth, and improved living standard [10].

Based on the data of waste composition in West Papua, 70% of solid waste is mainly originated from food scraps or leftovers, while the remaining 20% and 10% were originated from woods and paper respectively. In fact, most of solid waste produced in West Papua has not been managed properly. Households, industrial and commercial sectors usually dispose their solid waste to the waste bins that provided by the Environmental Service of local government in each area without any separations. Consequently, the wastes are taken by the local government service into an open dump or landfills for final disposal and yet to be treated.

By looking at the aforementioned facts, the awareness of waste management in West Papua is considerably low. Inadequate knowledge and lack of skills in waste management are the main concerns in empowering local people. Although the local government has already provided waste bins in certain areas, the separation of specific bins for organic and inorganic waste is yet to be established. Therefore, proper solid waste management is needed because any type of waste has an impact on GHG (greenhouse gas) emissions and pollutants. The alternative 3R methods (reduce, reuse, recycle) can be applied to reduce the volume of solid waste and implementing strong laws in handling/regulating solid waste to improve the quality of environmental sustainability and reduce carbon gas emissions into the atmosphere.

One of the problems in building proper waste management system is data collection. Most of wastes are just dumped and due to huge waste production per day from every households (not to mention other sectors), exact weight and volume measurement would be very difficult to be accounted. Hence, some approaches are required to estimate total waste produced. In this paper, total waste is estimated by involving total population and gross domestic regional product (GDRP) that easier to be obtained as main variables. Further calculation will be exercised using dynamic system model. System dynamics provides construction to rationally analyze the structure and its interactions in environmental systems [11].

Some previous studies has been conducted to estimate the waste production using dynamic models. Oriola (2014) demonstrated system dynamic to study the increment of waste generation and its waste collection effectiveness [11]. Muhsin et.al (2018) developed system thinking on understanding the abundance of litter generation on urban lake in developing country [12]. This paper emphasizes system dynamic model to estimate waste generation and GHG emission in accordance with NDC target of emission from waste.

In order to address the above problems, this study aims: (1) to assess GHG emissions from solid waste generated in West Papua from 2010-2030, (2) to propose the minimum portion of waste to be managed in order to maintain GHG emissions at convenient level with the available capacity in West Papua.

2 Method

This research was conducted in West Papua, Indonesia, which is located at 0° – 4^0 S latitude and 128°50' – 135°20' E longitude. The gathered data to support this research are total population in West Papua, Gross Regional Domestic Product (GDRP) of West Papua, annual income per capita and solid waste components that considered as independent variables in order to obtain the solid waste emission. All data is formulated using system dynamics model to simulate the GHG emission and its intervention for mitigation action. Variables relations of the solid waste emission in this study is simulated using *Powersim Studio Academic 2010*.

2.1 Variables Determination and Data Collection

In this paper, total waste generation is not only affected by total population but also growth of GDRP that represents income per capita. Hence, the variables and numbers that included in the system dynamics model are depicted as follows.

Table 1. General variables for solid waste dynamic model simulation

No	Variable Name	Unit	Source/Estimation Method
1	GRDP West Papua	billion	BPS Report West Papua 2010-2018 [9]
2	Total Population	number	
3	Solid Waste	ton	National Enviromental Quality Index Report 2010-2018 [13]
4	Landfill Capacity		

Table 2. GRDP, population number and solid waste generated in West Papua from 2010 to 2018

	GRDP (in Billion)	Population Number	Solid Waste (Ton) *	Landfill Capacity (Ton) **
2010	41,361.7	760,422	62,623.0	2,000,000
2011	42,867.2	785,979	64,186.9	2,060,000
2012	44,423.3	806,995	79,284.7	2,121,800
2013	47,694.2	828,293	87,223.9	2,185,454
2014	50,259.9	849,809	89,535.3	2,251,017
2015	52,346.5	871,510	91,908.6	2,318,548

2016	54,711.3	893,362	94,343.5	2,388,104
2017	56,906.8	915,361	96,843.7	2,459,747
2018	60,453.6	937,458	99,410.0	2,533,540

* : Due to limitation on solid waste source of data, the 2014-2018 solid waste numbers are generated using the average of dividing factor of historical population number and solid waste from 2010-2018.

** : Total landfill capacity is assumed at 2.000.000 ton with 3% extension per annum.

2.2 Dynamic System Modelling

In order to obtain the best scenario of low carbon emission from solid waste, this paper provides 2 (two) system models to depict the existing/bussiness as usual (BAU) waste generation and proposed model to reduce the GHG emission from waste.

- Business As Usual (BAU) Model
  For BAU, the model will provide interlink connection between total population, GDRP, waste and landfill capacity. These factors are crucial to represent the growth of waste rate every year. This BAU model becomes the groundwork to design the proposed scenario to reach low carbon emission from waste target.

- Proposed Model
  This proposed model will include some interventions as part of the scenario to reduce low carbon emission. The interventions will be elaborated as waste processing and treatment on landfill to reduce the amount of waste rate and consequently reduce the GHG emission.

2.3 Model Validation

Model validation is required to verify and identify potential errors on exercising the simulation. This validation will also ensure the behavior of the model has similiarities on actual records on field. In this paper, the validation process is using AME (Absolute Mean Error) method with equation as follows:

$AME = (Si - Ai)/ Ai \times 100\%$ (1)

where A is actual value, and S is the value of simulation.

3 Result and Discussion

3.1 Existing/BAU Scenario (2010-2018)

The existing/BAU of waste and emission factor is depicted on the model as follows.

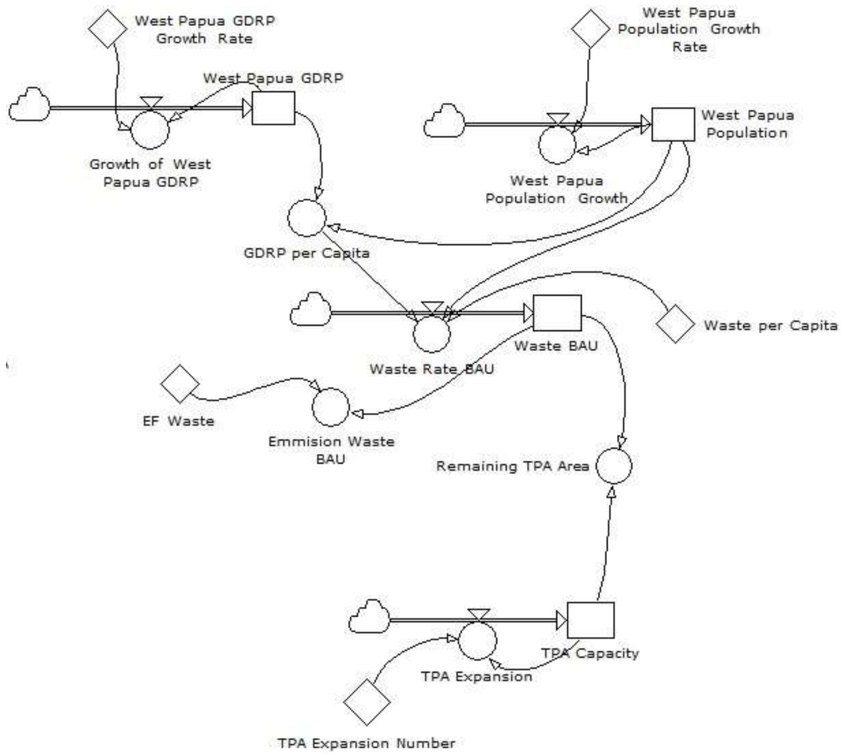

Figure. 1. Existing/BAU Simulation Model

As mentioned above, the rate of solid waste generation aligns with population and GDRP growth rate. Figure 1 depicts a model that based on historical data from 2010 until 2018, solid waste was keep increasing as the population and GDRP increased. This model also involved landfill (TPA) capacity as constraint and issue on managing waste on the area. In this paper, landfill capacity is assumed at 2 MT (millionton) wih 3% landfill extension every year. Not only landfill capacity, another concern raises on the issue of GHG emission that unavoidably kept increasing as the waste generation rate was unstoppable. The GHG emission rate is depicted on Figure 2 below. Since the waste are not specified (mixed dump), the emission factor that used in this calculation is 786 kgCO_2e/ton or 0.786 tonCO_2e [14].

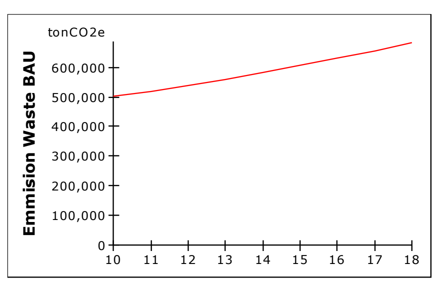

Figure. 2. Emission Rate BAU

Based on the BAU model (Figure 1) above, the GRDP growth rate in West Papua was 5.2% per year, while population growth rate was 2.65% per year during 2010-2018. At the same period, the solid waste rate was

93,877 ton per year, while the amount of waste produced per capita was 1.5 ton/billion or 15 kg/million. For validation, total GDRP and total population will be used as the parameters. The validation of this BAU model is depicted as follows.

Table 3. Validation of BAU model

Year	**Total GDRP (Billion)**		**Total Population (People)**	
	Data Collection	**Simulation**	**Data Collection**	**Simulation**
2010	41,362	41,362	760,422	760,422
2011	42,867	43,512	785,979	780,573
2012	44,423	45,775	806,995	801,258
2013	47,694	48,155	828,293	822,492
2014	50,260	50,660	849,809	844,288
2015	52,346	53,294	871,510	866,661
2016	54,711	56,065	893,362	889,628
2017	56,907	58,980	915,361	913,203
2018	60,454	62,047	937,458	937,403
Average	50,114	51,095	849,910	846,214
AME	**1.96%**		**0.43%**	

Based on the validation above, the BAU model is considered well representing the actual conditon on field with low AME of 1.96% and 0.43% of total GDRP and population of West Papua respectively. By exercising this model, the BAU activities of solid waste generation produced huge amount of emission at 682,073 tonCO_2e in 2018 and will keep increasing up to 1,135,577 tonCO_2e in 2030. Hence, this paper proposes new scenario to intervent the waste generated to be aligned with NDC target of emission from waste and propose certain area of landfill extension as depicted on Section 3.2 below.

3.2 Proposed Scenario (2021-2030)

Mitigation strategy will improve solid waste management and hence reducing the GHG emission from solid waste sector. Incineration can be proposed for one of the methods of reducing the effect of solid waste. As food waste comprise for the majority of solid waste in West Papua, incinerated the wastes reduces the energy and increase combustion efficiency [15, 16]. However, apart from incineration, there are more reliable recycling technologies such as anaerobic digestion for food waste [15, 17]. Anaerobic digestion can turn food waste into useful products which seems to be one of the most effective technologies [15, 17, 18]. The application of 3R (Reduce, Reuse and Recycle) of solid waste can be an option in a sustainable development strategy and has a profound socio-economic impact for climate change mitigation [19]. Therefore mitigation of solid waste through the strategy 3R for paper and wood wastes is a suitable option for reducing GHG emission.

For waste management efforts by the government, a management system that involves private and community participation is needed. Monitoring and evaluation of waste management is carried out by the government by involving the active participation of the community with the aim of ensuring waste management. The results of research conducted in a residential community obtained that the community was able to solve the problem of waste in their environment as a form of high awareness in responding to the problem of waste based on common interests. The proposed scenario involving the effort to reduce solid waste generation is depicted as follows.

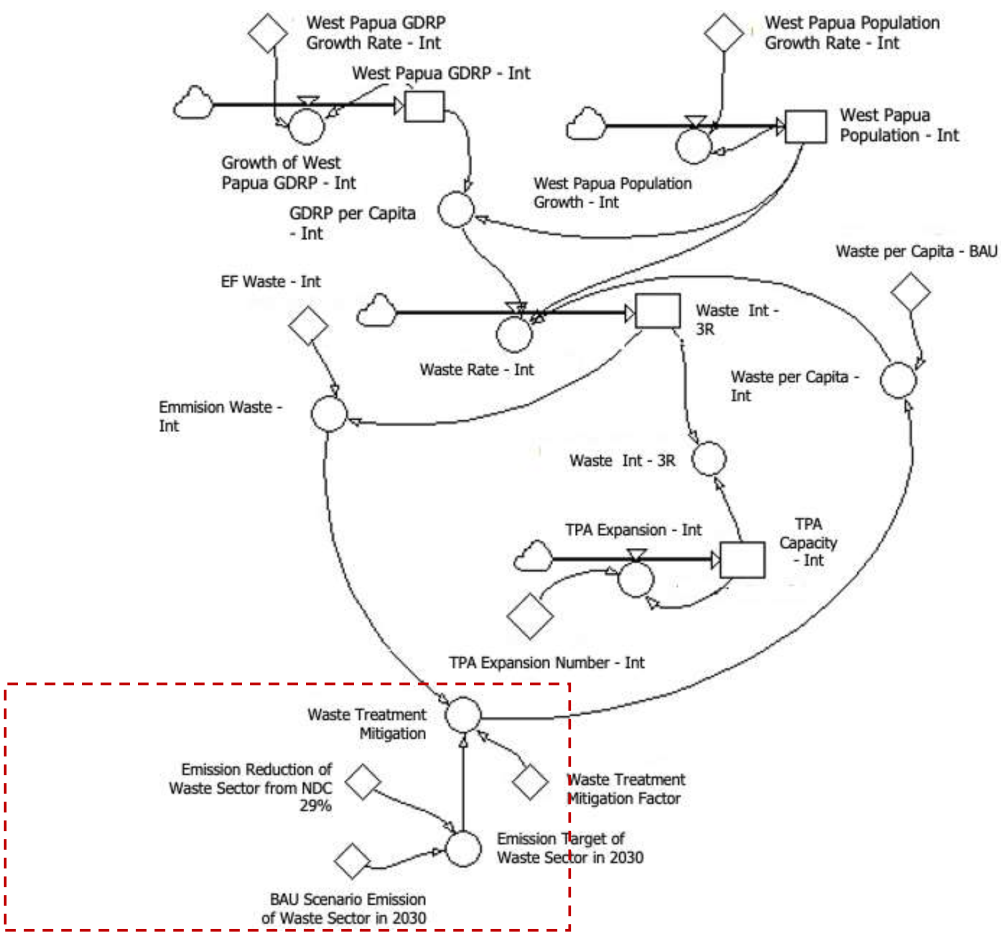

Figure. 3. Proposed scenario with waste treatment intervention

As depicted on Figure 3 above, intervention to mitigate the increasing waste rate is added by having waste processing and/or treatment. The amount of intervention is aligned with 29% NDC target reduction from waste emission as depicted on Table 4 below.

Table 4. Emission reduction target

Sector	2030 GHG Emission Rate (MtonCO$_2$e)		GHG Emission Reduction	
	BAU	CM1	(MtonCO$_2$e)	% of BAU
Waste	296	285	11	0.38%

By exercising the proposed model, total waste generated will be reduced to 2,991,409 ton compared with the existing/BAU model that will produce 3,785,257 ton in 2030. Total emission from waste also will be reduced up to 897,422 tonCO$_2$e or equivalent with 27% emission reduction which close to NDC target of 29% emission reduction. Not only waste intervention, this model also proposes extension of landfill capacity at 3% per annum to cater the rapid increment of solid waste generation. By looking at the following graph (Figure 4), the 3% per annum capacity extension would cater the need of waste landfill up to 2030 if the waste treatment was implemented.

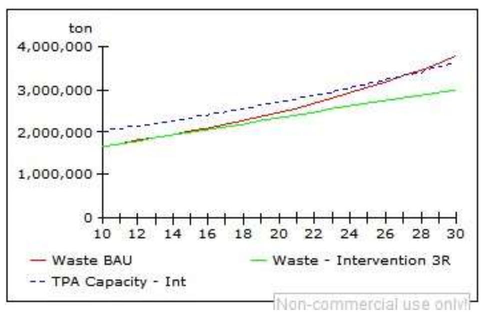

Figure. 4. Waste BAU vs waste treatment intervention vs landfill capacity

4 Conclusion

The aforementioned proposed models are able to estimate total solid waste produced and its GHG emission in West Papua. By 2030, West Papua will produce abundance of solid waste about 3.785.257 million ton and unavoidably produce GHG emission up to 1.135.577 tonCO2e if the BAU (business as usual) waste management remains. As part of the NDC target to reduce GHG emission, new scenario is proposed by applying intervention on the BAU model with proper solid waste treatment. By exercising the proposed scenario, West Papua is obliged to process their waste up to 118.297 ton/year to maintain the GHG emission at 897.422 ton CO2e in 2030 and meet the NDC 29% emission reduction target. In addition, landfill capacity should be increased by at least 3% per annum to cater the upcoming solid waste capacity as the the population and GDRP keep increasing. These models could be replicated to solve same issues in different areas and any further improvements are welcomed.

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Low Carbon Energy Model in West Papua

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Abstract. West Papua is one of Indonesian remaining forest frontiers that is expected to contribute greatly to countries' climate commitments. Although fast economic growth in West Papua may results in high emission to environment, especially in energy sector. The objective of this study was to simulate Gross Regional Domestic Product (GRDP) linked to Emission variables and integrating climate smart development. The dynamic system model will be used to integrate the influencing factors such as GRDP, capital, investment, and emission in West Papua. The modelling stage comprises of 1) concept drafting, 2) modelling, 3) model simulation, and 4) validation process. Data is gained from National Beureuracy of Statistics (BPS), and Bank of Indonesia Report. Powersim 10 is used to run the model. A causal loop diagram of the model initial scenario is formed of one variable is positive (reinforcing). Modeling results has been declared valid by the AME value of 4,96%. The implementation of NDC 41% in economic sector will cut GRDP to approximately a half than Business as usual GRDP. Based on the initial scenario, the model simulations indicate that the CO_2 emission along simulation period which is defined to year 2030 about 14,397,034,50 tonCO_2/year in average. After the structural intervention is conducted in the scenario, the CO_2 emission decrease up to 25,6%. **Conclusion**: Reducing emission acording to NDC 41% will correct economy. Utilization of friendly environmental energy resources is a solution to reduce emission and increase another sector such as tourism or public services maybe used to increase GRDP.

1. Introduction

Years before pandemic COVID19, Indonesia has experienced a stable macroeconomic growth since the last decade. This has succeededly catapult the nation as one of the largest economies in Southeast Asia. As of 2011, Indonesia is proclaimed as the 10th biggest country in terms of nominal GDP (PPP based) resulted in the improved credit rating to investment by Fitch and Moodys [1]. The country's experienced a steady economic growth at 5% during last year first quarter. In fact, the economic outlook of Indonesia showed a positive sign with median GDP growth of 5.1% constantly between mid 2015-2019 which remarkably in contrast with global economic downturn during the same period..

In spite of the favorable financial markers and steady growth, Indonesia still battles with poverty and unemployment, lacking infrastructure, corruption, and unequal asset distribution among locales. Despite being a forest-rich province, poverty in West Papua is rampant, although the trend shows some improvement. West Papua Province continues to experience growth, in 2010 the Gross Regional Domestic Product at constant prices [2], reached Rp. 41,362 billion and reached Rp. 60,454 billion in 2018. Such growth however does not reflect in the improvement of community welfare as shown in BPS 2016 data that around one-forth of the population still live in a destitute condition earning a meager 31 USD/month [3]. Development may open up more job opportunities, but without the experience or skills needed to seize such opportunities, West Papua will face stiff competition from migrant workers from another islands. Likewise, with investment that goes to the province, namely for plantations, indigenous Papuans will be hard to compete with immigrants or non-indigenous Papuans to work on plantation agriculture [4].

If the focus on development is shifted from business-as-usual to sustainable management plan, West Papua can better advance the target as set under NDC pledge in parallel with ensuring social prosperity on the ground. Current investment model in West Papua is still predominanted by the high emissions intensity industries such as cement industry, road infrastructure, oil and gas extraction, among others. One key characteristic of such investment is the high energy demand, one of the highest emiter, but contribute significantly towards economy growth -in mining and excavation, transportation, and business process [5]. Consequently, it creates brown development with high-emitting operational tool to generate economy. With the current scenario of experiencing such circumstance will more likely create adverse effect of environmental damage in the long run.

A low carbon energy model in Indonesia has been develop by Sadli. Sadli [6] use oil and gas consumption variable to construct a system dynamic model in energy, and use a larger scale of data of a nation, Indonesia. Until now, there is no research about low carbon energy model in West Papua especially using energy GRDP and emission as variable. This paper aims to build a low carbon economy model on energy sector to further understand, predict, and optimize the level of greenhouse gas emissions in West Papua Province based on the economic threshold and rationality of sustainable development in West Papua Province. Two key questions to address under this paper are: 1) How big is the potential emissions reduction under the low carbon energy scenario compare to business as usual scenario? and 2) what are the identified key indicators to support for low carbon economy in West Papua? The modeling results will be used as the basis for the formulation of the West Papua Province NDC policy and its implementation, as well as the basis for the West Papua Province Low Carbon Development policy.

2. Methods

2.1. The System Dynamics Model

This study uses the system dynamics model to simulate the real world system. It will assess different elements of the system (variables) that consist of stock, flow, and auxiliary. In system dynamics model, we recognized the importance of stocks and flows as the basis of the modeling. Here in the system, stock holds important role in representing affiliations in the system. On the otherhand, we represent flows by valve constructed by fusing diverse variables associated with economic management. It also presents the association between each element within a diagram.The feedback loops hence determines how different elements are interacted in a dynamic way. Such dynamic interaction can form the positive (supplementation relationship) as well as negative (opposite) relationship between different elements being assessed.

The modelling stage comprises of 1) concept drafting, 2) modelling, 3) model simulation, and 4) validation process.

a. Concept Design

Designing the concept is crucial to provide the groundwork on the expected BAU scenario and its intervention. It includes identifying the key variables to generate low carbon economy model, including economy-related indicators (of GDRP, investment rate, and capital) and environment-related indicators (of historical emissions and emission target in national and province level). Support from increased investment results in generating more capital which eventually, producing more regional income (Figure 1). The scenario performs reinforcing loop in causal loop diagram which create win-win solution for each elements in complementing each others.

b. Modelling stage

The interaction among elements are elaborated further into the Stock Flow Diagram (SFD) to process the model's behavior. SFD elaborates detail information on the correlation betweeen the determined elements over time, along with providing flexibility to run the model to gain result between the BAU and intervention scenario.

c. Simulation model

The computation simulation which is a solution to the problem is expressed in a mathematical model, using relationship between existing variables by testing the valid data. Mathematically, the model generally takes the form f (x) = y, where x = the set of information hidden in the model, in the form of quantities whose values must be determined so that real problems can be solved. Simple and complex mathematical models are used to answer the concrete problems faced. Due to the large number of these variables, a simulation is needed to perform these calculations indirectly with the help of computerization or software.

d. Validation of simulation results

The mathematical model is required for verification process to identify any potential error emerges after running the modelling scenario from SFD. The validation process is carried out to ensure the model behavior output is accurate and in line with expectations and realities in the field. We employe AME (Absolute Mean Error) to validate the process. The formula is as the following:

$$AME = (Si - Ai)/ Ai \times 100\% \quad (1)$$

Where A is actual value, and S is the value of simulation. We set the 30% as AME limit value which considerably strong enough to support the valid model [7].

2.2. Data

Data is gained by incorporating relevant indicators of social and economy, mainly from National Beureu Statistics (BPS), and Bank of Indonesia Report. The selected indicators were determined through expert elicitation to map the key elements involved under the low carbon development scenario. Powersim 10 is used to design CLD and SFD and run the model.

3. Result and Disussion

System dynamics (SD) introduced to shed a better understanding and enable us to visualize the complexities of dynamic system. Through system thinking, it is possible to use computer simulation to quantify and unpack causal relationships among different factors within the system as well as analyzing the feedback system and its dynamic relations. SD is a depiction of a system as a whole given its ability hence plays an important role in policy making arena [8]. It is important however to note the drawback of SD as it will require extensive data input for the system to operate properly. Data quality and realibility is still a problem in many countries, especially in places with low infrastructures. It is very common to find modellers employing data proxy when the acquired variables are not existed.

3.1. Causal Loop Diagram

Feedback concept is central to SD. We conceptualized system structure, by taking its complexity into account, by drawing upon ‘information feedback and circular causality’ diagram as seen on figure 1. The main CLD variables from the economy sector are obtained from GDP, Capital, Investment, and Emission. The CLD results from the main economy sector variables can be seen in Figure 1 [9]. In the ‘feedback loop’ (fig.1), we can see the reinforcing relationship between different elements in a positive interaction, forming a circular system. Such reinforcing relationship implies that positive changes on one component will affect the other components in positive way [10]. For example, incremental increase of energy investment in West Papua will be followed by increase of incoming capital (investment) and hence increasing GDP. This will also cost on the expense of increasing emission from the energy sector.

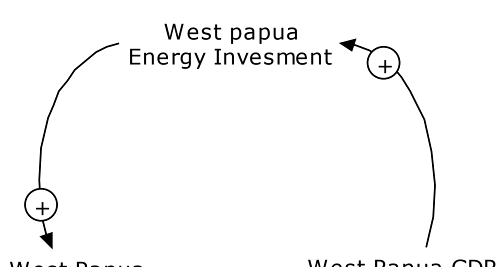

Figure 1. CLD low carbon energy in West Papua (PB)

3.2. Stock Flows Diagram

The second step of SD is Stocks flows diagram (SFD), also commonly known as modeling. SFD translates what is depicted in CLD through the use of selected symbols in the software.Although SFD comprises of main variables in CLD, it allows to incorporate new variables considered necessary but not yet used in CDL for the model to fully operate. [11]. An example is the dependency of PB emission on the GRDP and the Emission value.

In the figure 2 below, capital is a stock accumulated per annum, as the investments flows into the economic system. The investment is affected by PB Investment value and PB GDP. The capital of energy sector in PB in 2010 was 23,555 billion with the unit. Meanwhile, the investment is defined as PB Investment value multiplied by PB GDP. The PB GDP is also defined as PB capital in energy sector multiplied by PB COR (Capital Ration). COR Value of energy sector is 5.

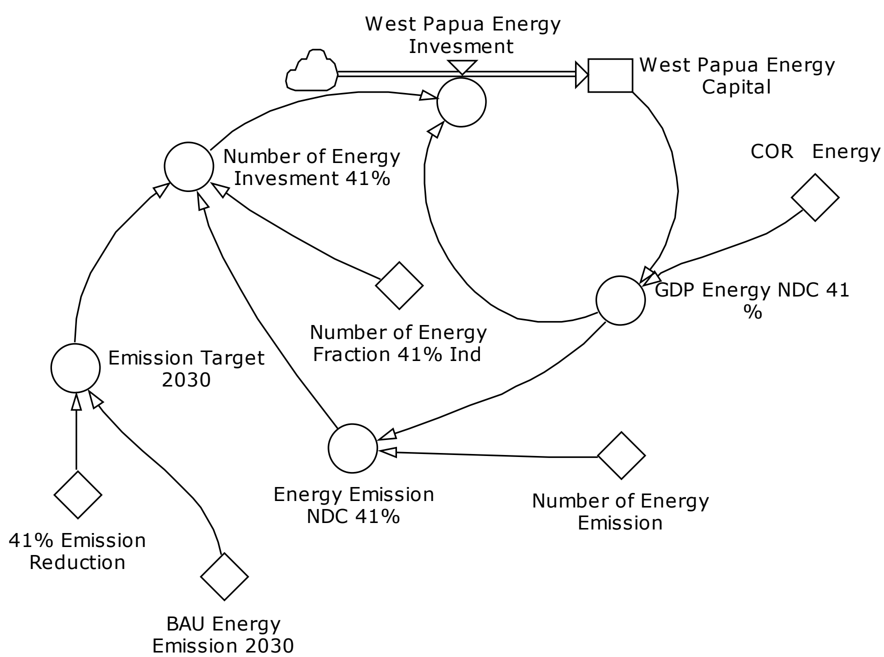

Figure 2. SFD low carbon energy intervension in West Papua

3.3. Simulation process

The model is built upon real world in a simple manner. This means model limitation to some extend become inevitable. In the system dynamic model, this is when assumption made important roles to overcome such limitations. The following lists are the assumptions we made for the low carbon economy model in West Papua:

a. Capital Energy is the total of Industrial and electricity and gasses sector from data recording from BPS Papua Barat. Capital Energy from household, agricultural and transportation sectors was ignored.
b. COR (Capital Output Ratio) Energy is the average of COR of Industrial and electricity dan gasses sectors from data recording from BPS.
c. GRDP (Gross Regional Domestic Product) Energy is the sum of Industrial and electricity and gasses sectors, while other sectors ignored.
d. Investation is gained from Industrial and electricity and gasses sectrors only.
e. Emission value is an energy emission from the use of energy in Industrial and electricity and gasses sectors, while used energy from household, agricultural and transportation sectors was ignored.
f. Emission Papua Barat BAU is emission from energy sectors based on BAU GRDP.
g. PB NDC Emission 41% is an emission from intervension 41%.
h. Investation value 41% an investation from intervension 41%.
i. PB emission target 2030 is a goal to reach low carbon economy in Papua Barat Province.
j. Emission reduction is a an emisson reduction based on Indonesian NDC 2030.
k. Emission BAU 2030 is an emission gained from BAU projection without any intervention.

The table 1 below shows the preliminary value of simulation and estimation methods.

Table 1. Initial value of simulation and estimation methods

No	Variable	Value & Parameter	Unit	Estimation method
1	GDRP	272134	Milyar	Secondary data
2	Capital	Estimated value	Milyar	Capital = 205 of GDP
3	COR	5		Secondary data
4	Investation	Estimated value	Milyar/Year	Investation = GDP*Investation factor
5	Investation factor	18	%	Secondary data
6	Emission	Estimated Value	tonCO_2eq	Sequestration – Total Emission
7	Emission factor	2925000	tonCO_2eq	Secondary data, IPCC (2007)
8	Emission target 2030	Estimated value	tonCO_2eq	Emission target 2030 = Emission BAU 2030 x Emission reduction
9	Emission NDC 41%	Estimated value	tonCO_2eq	Emission NDC 41% = GDP x Emission
10	Emission BAU 2030	Estimated value	tonCO_2eq	Secondary data, IPCC (2007)
11	Emission reduction	Estimated value	tonCO_2eq	Secondary data, IPCC (2007)

3.4. Validation Model

Furthermore, the economy sector model is validated using the Absolute Mean Error (AME) value with the following formula:

$$AME = \left| S\text{-}R \right| / R \qquad (2)$$

The notation of formula above is as the following:
S: simulation result average value
R: reference data average value

The model is valid if the AME value <0.3. Based on this formula, the economy sector validation can be seen in Table 2.

Table 2. Validation from energy GDRP management

Years	GDRP	
	Data Reference*	Data Simulation
2010	23.555	23.392
2011	24.121	24.248
2012	24.015	25.135
2013	25.302	26.054
2014	25.948	27.007
2015	26.400	27.996
2016	27.010	29.020
2017	27.257	30.081
2018	28.981	31.182
Average	25.843	27.124
AME	**4,96%**	

*Sources: [12][13][14][15][16][17][3][5][18][5][19]

The validation results in GDP show that the AME value is 4,96%. This value indicates that the AME value is >0.3, which means that the model is valid.

3.5. GRDP Energy Business as Usual (BAU) 2010-2030 predictions

Figure 4 represents the simulation GRDP of Papua Barats province simulation. As predicted, GRDP energy BAU increases from about 23,555 bilions in 2010 to over than 47,990.12 billions in 2030b (Figure 3). This condition is favorable for the economic development. On the other hand, prediction business as usual condition (without intervention) until 2030 shows the gradual increased of West Papua reaching about over than 14.3 GtonCO_2e in 2030 (Figure 4). The emission came from Industrial, and mining, and escavation sector. This condition leads to high accumulation of CO_2 in the air.

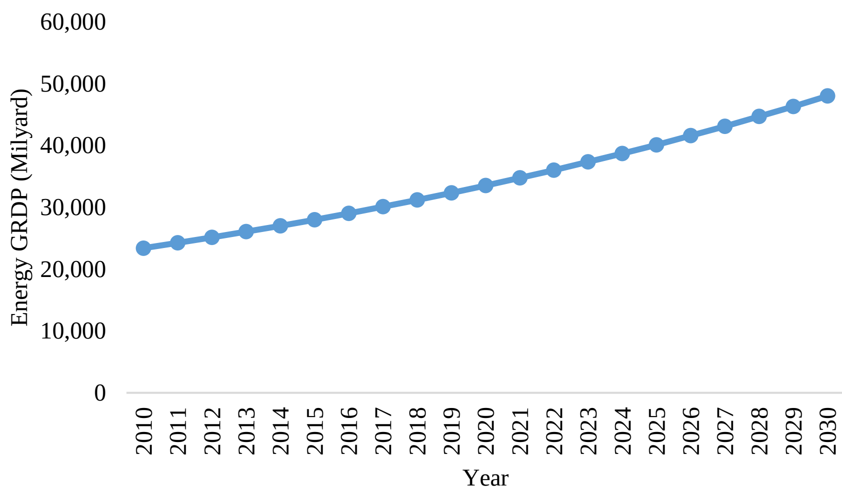

Figure 3. West Papua energy GDP Business As Usual

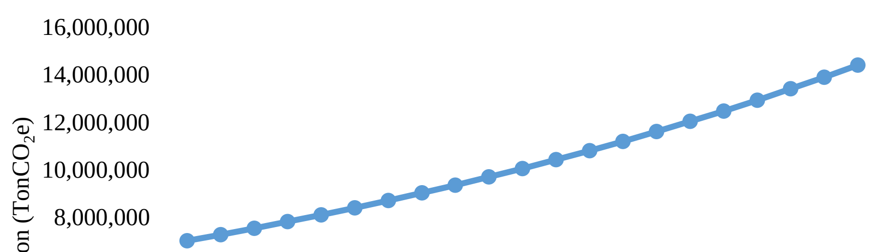

Figure 4. West Papua energy emission Business As Usual

3.6 West Papua Low Carbon Energy

Based on the condition resulted in BAU scenario, the economic will increase but emission in Papua Barat show a critical state. A new scenario have to be used to slow down the increasing of emission but did not correct the economy sector. Figure 5 below shows Papua Barat energy GDP with intervention of NDC 41%.

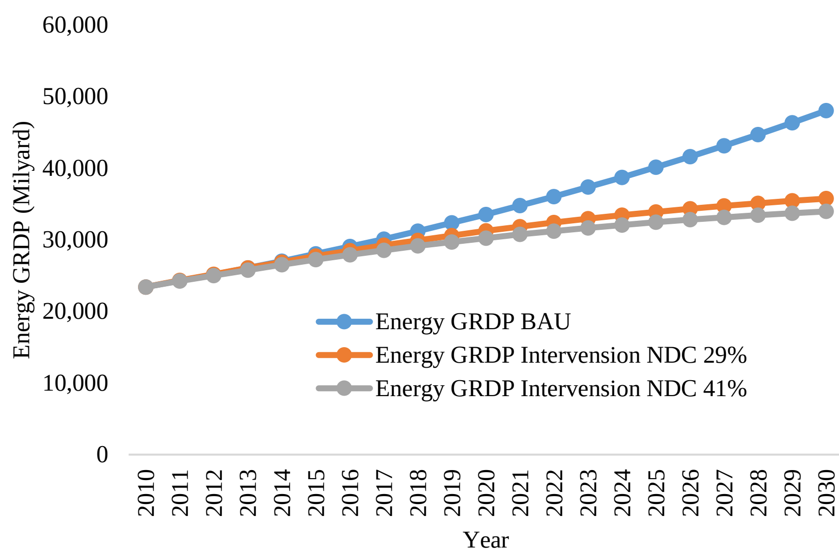

Figure 5. West Papua energy GDP NDC 41% intervention

The implementation of NDC 41% resulting a slow increase of GRDP (Line gray) compared with NDC 29%, and BAU scenario. West Papua province GRDP increases from about 23,392 billion in 2010 to above 47,990.12 billion in 2030, or almost double from baseline GRDP. In compare to BAU scenario, this figure is half of the estimate.

West Papua possesses 17 priority sectors that support Papua Barat economy. Implementation of NDC is likely to impact on GRDP negatively, therefore, there is an urgency to find other sectors to balance the GRDP if NDC commitments 29% scenario is established. Potential sector like ecotourism and agroforestry seem to offer promises to compensate the potential economic loss. Another sector is services industry such as financial and telecommunication hubs to support economic development.

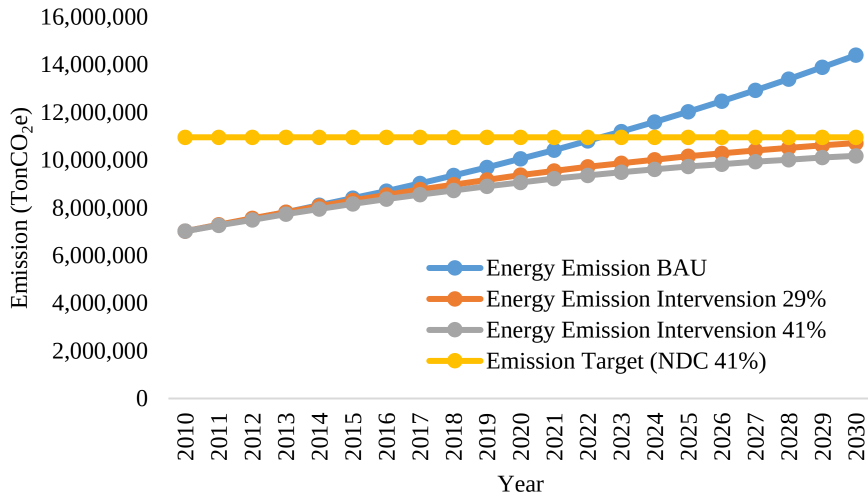

Figure 6. West Papua energy emission NDC 41% intervention

Furthermore, Figure 6 represents the West Papua emission with intervention NDC 29%. The intervention scenario will slow emission increases down but remains below the 2030 emissions target. The implementation of NDC 29% will reduce emission to a half amount CO_2e compared Business as usual scenario, or about 230 GtonCO_2e in 2030.

We estimated CO2 emission projection using 2 factors namely (1) the change of energy demand and (2) carbon emission. The 2006 IPCC recommended method then is employed to provide information on CO2 emissions factor for different energy types corrected value [20][21]. Conversion for power generation and heating from coal and LPG allocation from primary energy is hence referred as carbon emissions [22]. The West Papua Govenrment plans to use a wind power plant which did not produce emission into the environment. Beside that, energy from wave is very abundant in Papua Barat. One of many solutions to reduce emission in energy sector is to convert energy sources or mixing two sources of energy power plant, so the emission will be reduced.

4. Conclusion

The study observed the base case scenario for CO2 emissions during simulation up to 2030 reach up about 14,397,034,50 tonCO_2/year in average. If the NDC 29% intervension implemented on ground, CO2 emission could level down to 10,713,852,63 tonCO2/year or 25,6%.

A further research is needed, by including cross sectoral variables e.g. environmental and social in West Papua to establish a whole picture of the low carbon economy policy in the province.

Acknowledgement

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Development of the Sustainable Human Development Index Model in West Papua

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Abstract. The West Papua Province has declared itself as a sustainable development province by implementing various programs to achieve sustainable development goals (SDGs). The social, environmental, and economic factors in West Papua need to be linked to improve the HDI as one of the programs to achieve SDGs. The declining poverty rate in West Papua Province in 2010-2018 has had a significant impact on increasing the HDI of West Papua. This study aims to identify factors that affect the HDI as well as the dynamics and predictions concerning the Gross Regional Domestic Product (GRDP), agricultural sector development, and low-carbon development. This study uses the system dynamic method to understand the variables of economic and environment that affect the human development index. The simulation results indicate that the national GHG emission target can be achieved by a GRDP correction of 162.66 billion based on scenario 1 (29% reduction) and 115.55 billion based on scenario 2 (41% reduction). However, the West Papua HDI will only be corrected by 0.3 (Scenario 1) and 0.2 (Scenario 2). As the conclusion, the total GRDP of West Papua was corrected with emission reduction under the 41% reduction scenario, but it does not significantly affect the HDI of West Papua Province. **Keywords:** Human Development Index, Human Resources Investment, Gross Regional Domestic Product, Sustainable Development

1. Introduction

At present, the world has embraced the SDGs (Sustainable Development Goals), following the end of the MDGs in 2015. The SDG concept is a concept that emphasizes the implementation of sustainable development which consists of universal common goals, i.e. being able to balance the three dimensions of sustainable development consisting of environmental, social, and economic aspects. [1]. Sustainable development is defined as a conscious and planned effort to integrate environmental, social, and economic aspects into a development strategy that ensures environmental integrity as well as the safety, capability, prosperity, and quality of life for the current and future generations. The implementation of SDGs is expected to focus on five key foundations, namely people, planet, prosperity, peace, and partnership [1]. Furthermore, sustainable development serves as a means for achieving three noble goals by 2030, i.e. eradicating poverty, achieving equality, and overcoming climate change. Implementation of sustainable development agenda in Indonesia has been mandated in the level of regional authority [2]. The implementation of sustainability at the regional level is considered important because of some reasons such as the regional level is more manageable and can be considered as a vehicle for integrating sustainable development principles into regional development [3][4][5]. Implementation of sustainable development in regional can be counted as the key to having clear objectives of implementation SDG at the national level [6].

West Papua Province has declared itself as a sustainable development province. This creates challenges in its implementation as the province is actively executing development activities in various sectors. The

West Papua Provincial Government has implemented various programs, such as programs to eradicate poverty and improve the quality of human resources. The development efforts carried out are strongly supported by the variety of natural resources available. However, the availability of natural resources cannot sufficiently guarantee successful development for the prosperity of the people of West Papua. In addition, the quality of human resources and development management needs to be improved to achieve this success.

Social issues are currently under the spotlight in West Papua such as unemployment, poverty, and health (stunting) issues. In general, poverty can be defined as the inability of an individual to meet their basic needs (food, clothing, housing, education, and health) as well as limitations in meeting their economic, social, and other standard needs [7]. Statistic Bureau of Indonesia (BPS) data for 2010 - 2018 shows that the poverty rate has declined. The poverty rate in West Papua was 23.01 percent in 2018 and 22.17 percent in 2019 [8]. This indicates that the components forming the Human Development Index, such as health, education, and people's purchasing power have improved. Poverty is caused by various factors, such as low education, low health standards, limited employment opportunities, lack of resource ownership, isolated conditions, and/or local topography [8]. Poverty can be a lack of nutritious food, insufficient availability of clean water, inadequate housing, lack of health services, and low levels of education [8][24][25]. The level of poverty is closely related to HDI, meaning that a high HDI tends to reduce poverty.

The Human Development Index can be defined as an effort to provide more options for the population through empowerment efforts that prioritize the improvement of basic abilities so that they can fully participate in various development sectors [9]. The HDI describes the condition of a population or human resources in an area or province. The HDI measures the overall achievement of a province based on the three dimensions of Human Development i.e first life expectancy - measured by life expectancy at birth; second, education - measured by the mean years of schooling and expected years of schooling; third, decent standard of living - measured by real income per capita (expenditure) [8][27].

The increase in HDI was a result of the contribution and allocation of government expenditures for the education, health, and infrastructure sector. The budget allocation for the education and health sectors in 2010-2018 tended to fluctuate, alternately increasing or decreasing from year to year. However, the largest allocation for both the health and education sectors was in 2014, i.e. Rp. 682,850,044,956 (health sector) and Rp. 1,280,719,000,638 (education sector) [10]. Government expenditures on education and health can be classified as an investment in human resources or investment in the HDI. Several studies have shown that government expenditures in the education and health sectors correlate with the HDI [11][12][13]. We can conclude that government expenditure on education has a significant positive effect on HDI [14]. Another research that was resulted from Yuliana [15] stated that there is a significant relationship between the human development index (HDI) and poverty.

The increase in Gross Regional Domestic Product (GRDP), along with the increase in HDI, was observed in 2010 - 2018 [8][16][17][18]. The increase in GRDP, especially agricultural GRDP in West Papua is a positive aspect that contributes to increasing the HDI, with regards to the number of people working in the agricultural sector. The improvement of the prosperity of the people of West Papua depends on the development strategy in environmental, social, and economic aspects. The implementation of the three aspects are interrelated and influence each other, hence it is not addressed partially [11][12][13]. Development and accuracy in governance for each aspect are crucial in reducing or eradicating poverty in West Papua. Based on the description above, through the study of the HDI model in West Papua, its development can be seen and also other variables related to HDI during the period 2010 - 2018.

The research objective is to determine the development of West Papua's HDI as well as the best scenario by developing a system dynamics model, which will provide solutions and benefits to support policymaking to sustainably increase West Papua Province's HDI. The modeling and simulation in this study are used to model the Human Development Index in West Papua. The modeling includes HDI figures and several other influential variables. The modeling simulation results are expected to assist in increasing the HDI as a success indicator for developing the quality of human life in West Papua.

2. Method

The system dynamics method is a problem analysis method conducted by imitating a system or abstraction form of complex, dynamics, non-linier, and have a feedback [23]. In this study, modeling and simulation are used to model the Human Development Index in West Papua in 2010-2018. Causal Loop Diagram, The initial stage in dynamic system simulation is to formulate a model according to the existing conditions of the Human Development Index in West Papua. An important element in the Causal Loop Diagram (CLD) concept is to identify and connect between each variable that affects the development of the Human Development Index in West Papua. Stock Flow Diagram, The next stage is to create a flow diagram that can be divided into several sub-models. This stage is to see the pattern of relationships between variables in the simulation and to see the suitability of the model with the facts in the field. The verification and validation phase aims to ascertain whether the behavioral output of the model is accurate, true and acceptable. Scenario and Analysis Stage, based on the simulation result data on a valid model base with original data, the next step is to develop a scenario.

2.1 *Model description*

The System Dynamics method can analyze models and policy designs that focus on the dynamic issues identified in social aspects. Identifying variables related to and affecting the HDI. The CLD analyzes the pattern of the relationship between the GRDP, HR investment, and HDI figures. In addition, it also looks at the poverty aspects of the population. The System Dynamics Method is implemented under the following stages: (1) Creating Causal Loop Diagrams, (2) Preparing Stock Flow Diagrams, (3) Verifying and validation of the model, (4) Preparing scenarios and analyzing results.

2.2 *Data*

The data used in this study are secondary data from the selected economic, social, and environmental indicators. Time series data (for 8 years, from 2010 - 2018) is used in this study. The data used comes from Statistic Bureau of Indonesia (BPS) and several reports concerning the environment and socio-economy. The modeling in this study is prepared using the Powersim 10 software.

2.3 *Causal Loop Diagram*

The results of creating a social system dynamics simulation in West Papua by formulating a model, which is also adjusted to the existing conditions of the social aspects in West Papua. The Causal Loop Diagram (CLD) concept in the case of the social aspects in West Papua is prepared by identifying and connecting the relationships between each variable. In this case, the types of variables and the patterns of relationships between variables can be identified. A number of variables have been identified for social aspects, such as ecosystem degradation, carbon absorption, carbon emissions, capital investment, GRDP, capital investment in health and education, population growth, poverty which affects the HDI of West Papua Province.

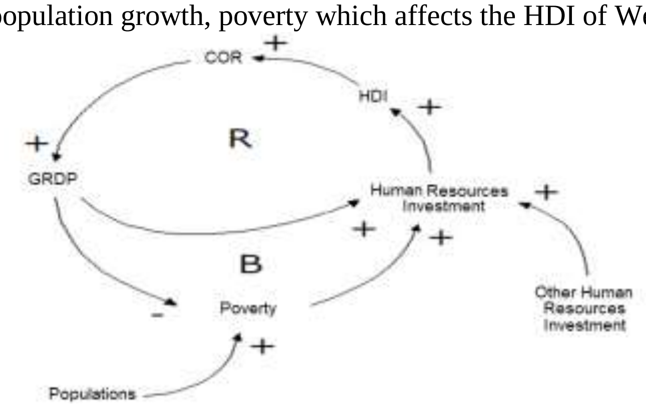

Figure 1. CLD Diagram

Figure 1 above indicates that two loops are reinforcing and balancing. The HDI will increase in line with the increase in human resource investment as a result of the GRDP increase which also reduces the poverty rate. However, the poverty rate will also increase following the growing population.

2.4 Stock Flow Diagram

Data modeling and the creation of the flow diagram are divided into several sub-models. Data modeling is carried out to determine the behavior patterns and relationships between each variable in the simulation to determine the suitability of the model with behavior in real conditions. The implementation of data modeling is illustrated with a causative diagram. Upon creating a causative diagram, the flow diagram will make it easier to prepare the scenario modeling. The implementation of creating a flow diagram is as follows:

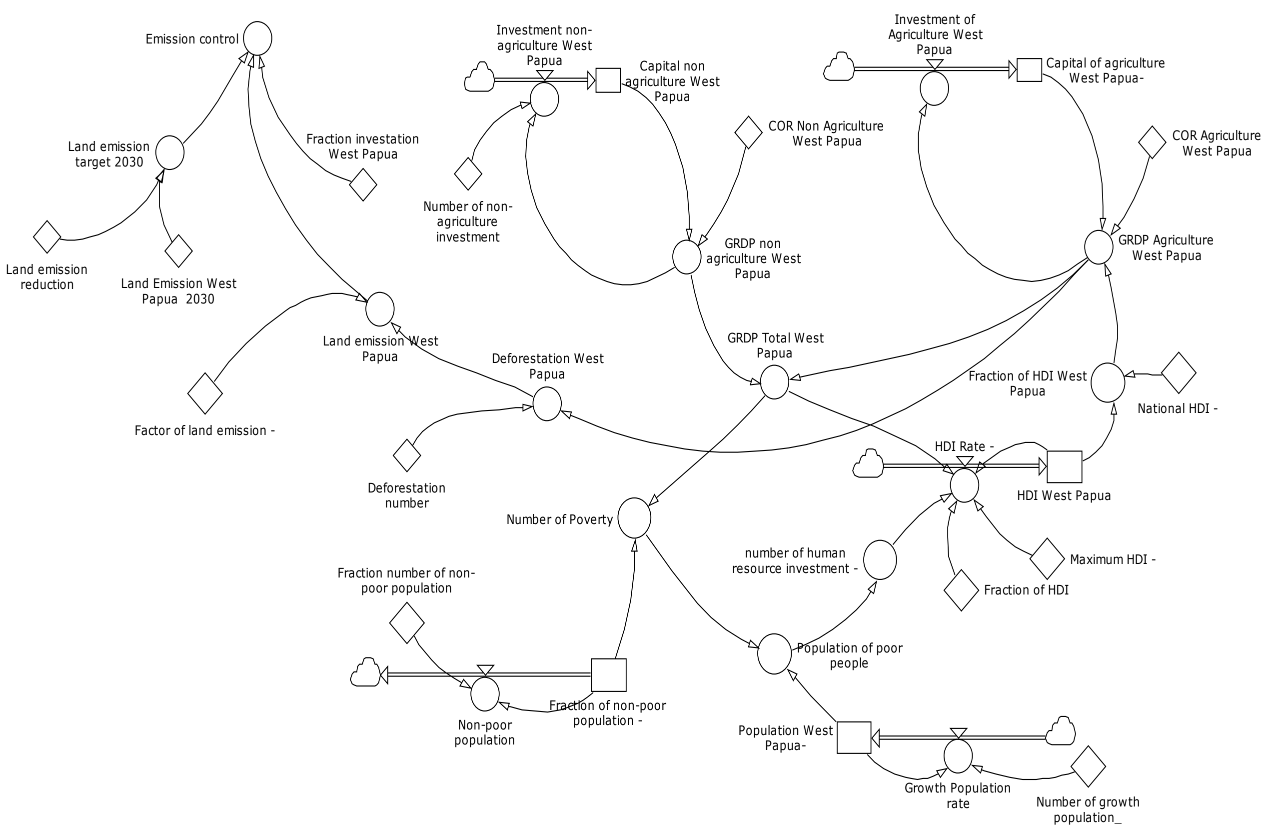

Figure 2. Stock Flow Diagram

Figure 2 shows an SFD consisting of economic, forestry, and social factors. The GRDP affects the HDI, likewise, the GRDP affects poverty. The GRDP is partially influential on HDI and poverty. In addition, Agriculture GRDP directly affects the deforestation rate. Two scenario simulations were also carried out in the SFD. Scenario 1 covers treatments or policies for reducing land emissions by 29%, while Scenario 2 covers treatments or policies for reducing land emissions by 41%.

The human development index modeling in West Papua Province is built on the following assumptions:

1. Agricultural COR refers to the average COR of the agricultural sector based on the statistic data.
2. Agricultural Investment refers to investment in the agriculture sector.
3. Agriculture GRDP refers to the total contribution of the agricultural sector to the GRDP.
4. Agricultural Capital refers to the total agricultural sector in West Papua Province.
5. West Papua's BAU land emissions refer to emissions from the agricultural sector based on the GRDP BAU

6. The 29% Emission West Papua NDC refers to emissions from the 29% intervention
7. The 29% investment amount refers to investment from the 29% intervention
8. The 2030 West Papua emission target refers to West Papua Province's target to achieve low carbon development
9. Emission reduction refers to a reduction in emissions based on Indonesia's 2030 NDC
10. The 2030 BAU emissions refer to the emissions obtained from the BAU projection without intervention.
11. The population growth rate remains constant at 2.65%/year.
12. The National HDI is assumed to remain the same as the 2010 National HDI
13.

Some of the variables used in the modeling system are shown in the following table.

Table 1. Variables of Model

No	Variable name	Value Parameter	Unit	Estimation Method
1	Agricultural Capital	3,459.78	billion	Agriculture GRDP (BPS, 2008-2018) x Agriculture ICOR (Bappeda, 2017)
2	Non-Agricultural Capital	199,626.03	billion	Non-Agriculture GRDP (BPS, 2008-2018) x Non-Agriculture ICOR (Bappeda, 2017)
2	Agricultural Investment Figures	33.68	%	Agricultural Investment Data (BPS, 2008-2018)
3	Non-Agricultural Investment Figures	26.58	%	Agricultural Investment Data (BPS, 2008-2018)
4	Deforestation	129.93	ha/billion	Deforestation Data (BPS, 2008-2018)/Agriculture GRDP
5	Land Emission Factor	72.33	tonCO2e/ha	Carbon stocks from primary and secondary forests (IPCC, 2007)
6	Population growth	734,661	person	Population Initial Value (BPS, 2010)
7	Human Development Index of West Papua Province	59.47	%	Initial value of West Papua Province HDI (BPS, 2010)
8	Human Development Index of Indonesia	66.53	%	Secondary data

2.5 *Simulation and Validation of the Model*

The validation of the model is done by comparing population data, the HDI, and the simulation results for the current year. This output comparison is then analyzed using the Absolute Mean Error (AME) using the equation below. The model can be accepted if the AME is <0.3.

$$AME = \left| Data - Simulation \right| / Simulation \qquad (1)$$

The following table presents the model validation data with the Agriculture GRDP and the HDI of West Papua in 2010 - 2018.

Table 2. Validation of the Model

Years	Agriculture GRDP (Billion)		HDI	
	Reference Data*	Simulation Data	Reference Data*	Simulation Data
2010	1,406	1,406	59.60	59.47
2011	1,388	1,426	59.89	59.60
2012	1,338	1,446	60.29	59.74
2013	1,375	1,467	60.90	59.89
2014	1,424	1,489	61.27	60.04
2015	1,491	1,511	61.73	60.20
2016	1,523	1,534	62.21	60.37
2017	1,558	1,557	62.99	60.55
2018	1,581	1,582	63.74	60.74
Average	1,454	1,491	61.40	60.07
AME	2.56%		2.18%	

Based on the validation results for the Agriculture GRDP, the AME equals 2.56% or 0.025, hence the model is declared valid because the AME is <0.3. The validation of the HDI equals 2.18% or 0.0218, hence the HDI model is also declared valid.

3. Results and Discussions

3.1 *Total GRDP BAU, Total GRDP Scenario 1 (29%) and Scenario 2 (41%) in West Papua*

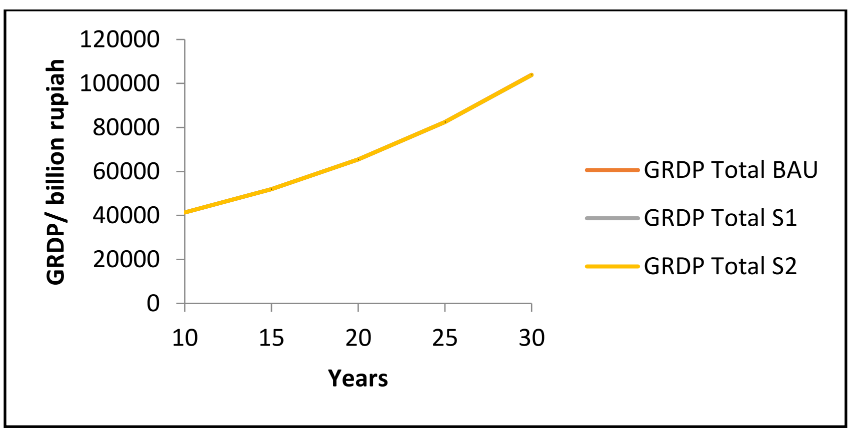

Figure 3. West Papua's Total GRDP

Figure 3 shows the GRDP of West Papua in the 2010-2030 period linked to the scenario 1 (S1) and scenarios 2 (S2). Based on the BAU simulation results, the total GRDP of West Papua is predicted to increase, i.e. Rp 41,361.72 billion in 2010 and reaching Rp 103,976.57 billion by 2030. The simulation results of the scenario 1 with 29% emission reduction show that by 2030 the GRDP of West Papua will be slightly corrected from the BAU GRDP of 162.66 billion On the other hand, the scenario 2 with the 41% emission reduction shows that the GRDP is corrected by 115.55 billion. This shows that the sustainable development of the economy in West Papua is successful due to an increase in the total GRDP of West Papua Province.

Table 3. GRDP Total of West Papua

Year	GRDP Total BAU	GRDP Total S1	GRDP Total S2
10	41,361.72	41,361.72	41,361.72
15	52,022.50	52,005.63	52,018.99
20	65,486.71	65,439.79	65,465.84
25	82,493.36	82,399.36	82,436.84
30	103,976.57	103,813.91	103,861.02

3.2 *BAU Agriculture GRDP, Scenario 1 (29%) Agriculture GRDP and Scenario 2 (41%) Agriculture GRDP of West Papua*

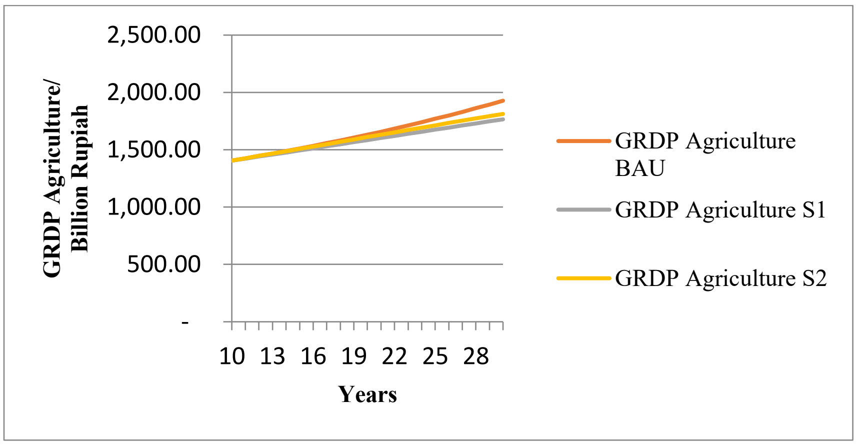

Figure 4. West Papua Agriculture GRDP

Figure 4 shows West Papua Agricultural GRDP in relation to scenario 1 (S1) and scenario 2 (S2), associated with achieving GHG emissions in 2030. West Papua's Agriculture GRDP is quite low or only contributes approximately 3.4% of the total GRDP, i.e. 1927.83 billion (BAU), 1765.17 billion (S1), and 1812.28 billion (S2) by 2030. However, this sector continues to experience growth from 1405.72 billion (BAU), 1423.24 billion (S1), and 1425.94 billion (S2) in 2010. The interventions under S1 and S2 slightly reduce the Agriculture GRDP, but the value still falls within the range of one hundred billion rupiah. This shows that the interventions implemented as an effort to reduce GHG emissions to achieve the 2030 emission target can be carried out although slightly correcting the Agriculture GRDP and the overall GRDP. Therefore, better policies are needed in this sector so production can increase and the harvest can be sold at a decent price which will, later on, attract more business actors to this sector.

3.3 *GHG emission simulation results on BAU land emissions, Scenario 1 (29%) land emissions, Scenario 2 (41%) land emissions, and Land emissions Target 2030 in West Papua*

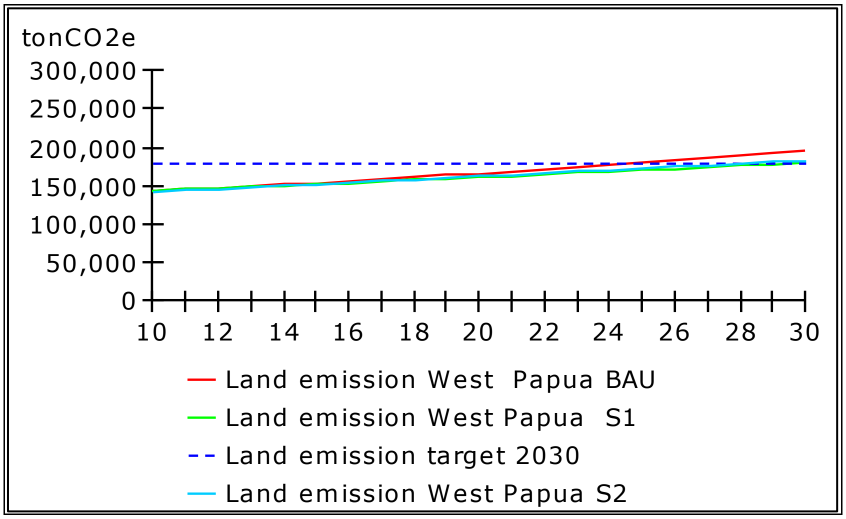

Figure 5. West Papua Land Emissions

Figure 5 shows the state of West Papua's GHG levels in 2030 based on scenario 1 (S1) and scenario 2 (S2). In general, we can see that the interventions carried out in scenario 1 and scenario 2 has reduced GHG emissions compared to the BAU. The simulation data shows that if there is no intervention (BAU), the GHG emission of West Papua Province will reach 179570.31 tonnes of CO_{2eq} by 2030, which is slightly higher than the 2030 GHG emission target of 181367.16 tonnes of CO_{2eq}. With interventions under scenario 1, this figure can be slightly reduced to 179570.31 tonnes of CO_{2eq} below the 2030 GHG emission target. With interventions under scenario 2, the figure becomes 184363.36 tonnes of CO_{2eq} which is slightly higher than the emission target. This shows that interventions need to be implemented to achieve the 2030 GHG emission target.

3.4 *The results of the HDI simulation on the BAU , Scenario 1 (29%) , and Scenario 2 (41%) in West Papua*

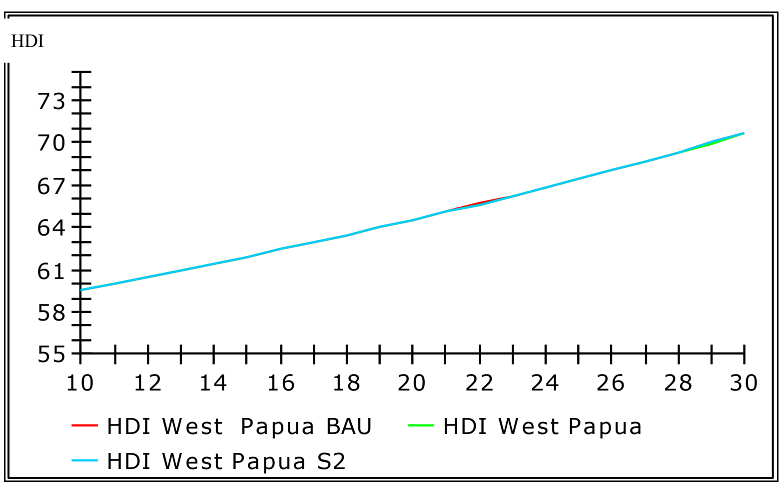

Figure 6. Human Development Index of West Papua

Figure 6 shows the state of development of West Papua HDI 2010-2030, which is associated with GHG emission reduction interventions in scenario 1 (S1) and scenario 2 (S2). Although the interventions were implemented to reduce GHG emissions, apparently the increasing HDI remains almost unaffected by all scenarios. The simulation shows that the 2010 HDI is 59.60 and will increase to 70.68 (BAU), 70.65 (S1), and 70.66 (S2) by 2030. The total GRDP also continues to grow in a positive direction, despite a slight decrease in the Agriculture GRDP. This shows that scenario 1 (S1) and scenario 2 (S2) interventions can be successfully implemented without inhibiting economic growth as evidenced by an increase in GRDP and HDI.

4. Conclusion

Based on the simulations carried out until 2030, it can be concluded immediate control through various interventions are required to reduce GHG emissions based on these two scenarios, the S1 scenario can successfully reduce HG emissions to 179,570.31 tonnes of CO_{2eq}, lower than the 2030 GHG emission target for West Papua of 181,367.16 tonnes of CO_{2eq}.

The simulation results also indicate that the total GRDP of West Papua was corrected by efforts to meet the national GHG target. However, this decline only occurred in the Agriculture GRDP with the largest reduction of 162.66 billion (S2), while other sectors remained unaffected. On the other hand, there was almost no effect on the level of social welfare as shown in the HDI figure which is only corrected to 0.3 (S1) and 0.2 (S2).

As a suggestion from this research, sustainable development with a national GHG emission reduction target requires strict control from the relevant government apparatus so mitigation in the framework of deforestation can be carried out whilst continuously encouraging economic growth and achieving the national GHG emission targets which will further improve public welfare as reflected in the increasing HDI of West Papua.

Acknowledgment

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Towards an Eco-Industrial Development in West Papua Economy

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Abstract. West Papua province holds key role to ensure the NDC target could be achieved in measurable and timely manner. Despite its rich possession of pristine biodiversity, manufacture industry contributes 3% of the provincial total income. This study aims to predict the GRDP if West Papua incorporates Eco-Industrial Development (EID) to mitigate emissions from 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 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 along with 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, while the contribution to external region's economy could decrease from 230 billion IDR to 180 billion IDR. Besides the benefit of EID to reduce emissions, the government should also take into account the impact of economic contraction.

6 Introduction

Eco Industrial Development (EID) refers to the 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 green economy by creating socio-economic opportunities on low-carbon agenda and increasing adaptability from the adverse effect of climate change [2].

Sub-national contribution has pivotal role to achieve sustainable development and NDC target. West Papua Province as Indonesia's last forest frontier holds imperative role to achieve low carbon development goals. Having forest cover area of 90% out of total, apparently it does not contribute significantly towards the regional income. The regional income from land-use sector contributes about 6,050 billion IDR or 10% in 2018. In the last five years, industry sector, including the Coal 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]. In addition, it also stimulates the growth of other sectors including increasing the work participation rate by 68.27% [4].

Therefore, restructuring the economy framework is required in order to fully optimize the availability of local resources in West Papua. With its geographical conditions and biodiversity, the driving force for industrial sector should involve sustainable aspect within the business process. The transformation can be in the form of technological 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 labor and capital [7].

Research from Labiba & Pradoto (2018) shows that the intensity of CO_2 emissions from industry-related operations has potential to steadily increase through 2031 [8]. 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 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 in during 2012-2016 generated from 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 toward external resources such as skilled labor and imported products including raw materials. Therefore, industrial transformation is needed to reduce reliance on imports of goods and services.

Conrad & Kulkarni (2009) introduces the "Big Push" concept, stating that policy development must be pursued through changes in fiscal and monetary policies that affect economy growth [11]. In this regard, it is important 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 own activities (backward linkage), that are shaped by stages to boost 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 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 global economy through the integration of West Papua economy with global economy outside West Papua? In addition, 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 is calculated in energy sector.

7 Material and methods

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 behavior of the system; and 3) the redesign of a model with new defined characteristics [12]. In this research, 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 designed to measure the value added of industrial sector if the level of emissions is maintained at a certain level. The modelling stages include conceptualization, modelling, simulation, and validation.

7.1 Model description

The system dynamics model is used to interlink variables with other intertwined aspects, including industrial value-added 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 system dynamics model namely stock variable, flow variable, and additional variable. The stock variable is often referred as level variable, describing the main associations of the system. The flow variable is indicated by the valve, created by combination of investment-related features in 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 arrow in the diagram. The interaction is negative (-) if 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 time period. To better recognize the model's behavior, several scenarios are tested in the simulation model. The scenario is expected to demonstrate the ability of capital to boost economic benefit from industry sector.

7.2 Causal loop diagram

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

Figure 1 shows 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 manufacturing industry and social welfare of local communities. There is a reinforcing loop (R1) perpetuating the increasing of GHGs emission from 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 controlling the GHGs emission from Industrial Sector, as well as, implementing eco-industrial development concept in West Papua.

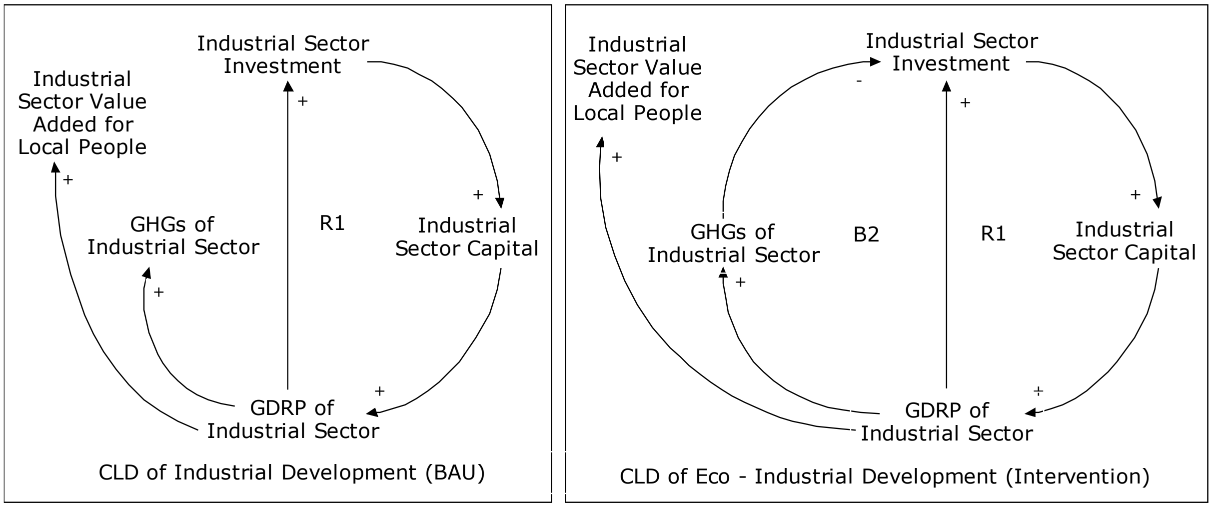

Figure 1. Causal loop diagram of Industrial Sector.

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

7.3 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).

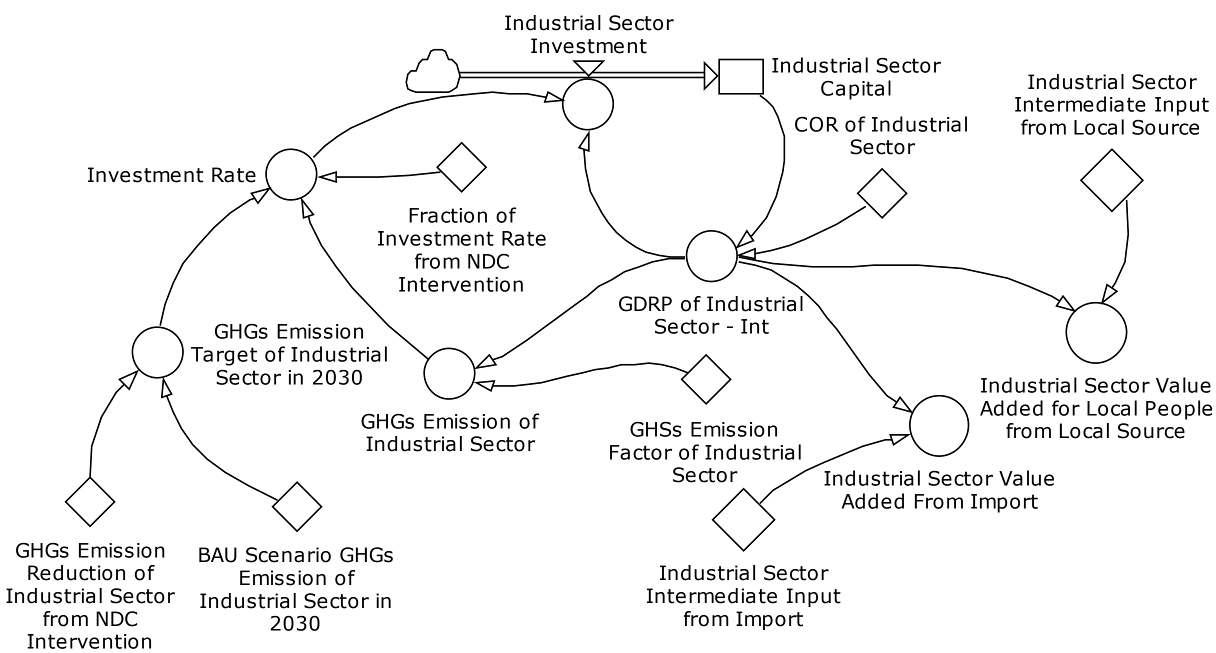

Figure 2. Stock and flow diagram of Eco - Industrial Development.

The model simplifies the dynamics of the real world, hence limitations exist under the model. COR element provides a value added to industrial sector, while GHG emissions element influence investment scheme. The model emphasizes emissions reduction target to meet with the national target under 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 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$_2$e	Secondary data
4	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 Industrial Sector in 2030	71,959.543	tonCO$_2$e	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	

No	Variable	Value / Formula	Unit	Data Source
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 Industrial Sector in 2030	'BAU Scenario GHGs Emission of Industrial Sector in 2030' * (100<<%>> - 'GHGs Emission Reduction of Industrial Sector from NDC Intervention')	tonCO_2e	
14	Industrial Sector Value Added for Local People from Local Source	'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	

7.4 Simulation and validation of the model

At this point, the model is successively validated 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).

$$AME = [Si – Ai] / Ai \times 100\% \quad (1)$$

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

The AME value uses 30% limit value, this value is correlated with number of 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 is calculated in 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	

8 Results and discussions

Figure 4 is a simulation of West Papua Province Industrial GRDP. Under the BAU scenario, industrial GRDP is projected to rise from about 1,200 billion in 2010 to over 2,500 billion in 2030, while 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.

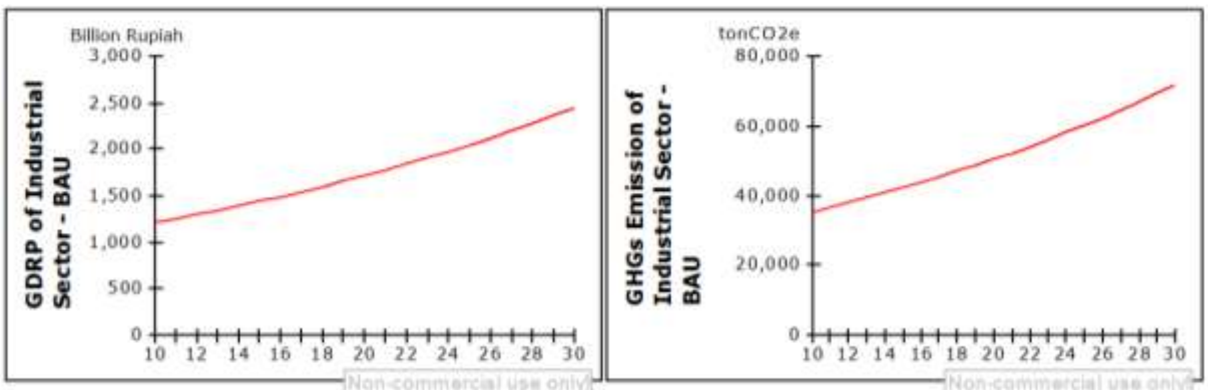

Figure 4. Simulation results **of Business-As-Usual (BAU) Scenario.**

8.1 Industrial sector GRDP and GHGs emission in West Papua

Figure 5 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 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 of emissions. Figure 5 shows West Papua GRDP of 29% and 41% NDC target in 2030 for reducing GHGs emissions toward its base year of 2010 (EID scenario).

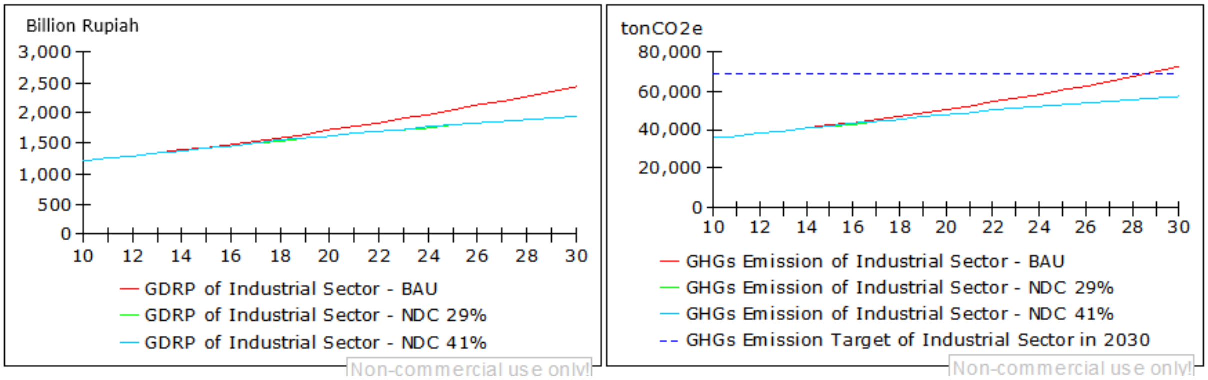

Figure 5. Simulation results of industrial sector GRDP and GHGs emission.

Figure 5 (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 the Figure 5 (right), the emissions produced from all scenarios also will rise within 2 decades. Hidayatno *et al.* (2018) explains this rising phenomenon as the impact of the fuel combustion activities in 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.

In a contrary, both of the EID scenario of NDC 29% and 41% can reduces 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 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 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 provincial development plan. Based on the simulation, it is important to take into account the contraction of GRDP in 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.

8.2 The integration of West Papua regional economic development with global region

Figure 6 simulations show the relationships between 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 global economy as well. It shows the intermediate input import have increased the GRDP of industry in West Papua under both of 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 labor production factors (the indicator is not visualized in the model). Thus, the value added gained by local people for the local inputs in industry sector is comparatively higher than the gain of the West Papua economy from import-to-import input (Figure 6). The result is consistent with the fact that a huge 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 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 global economy. Under 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.

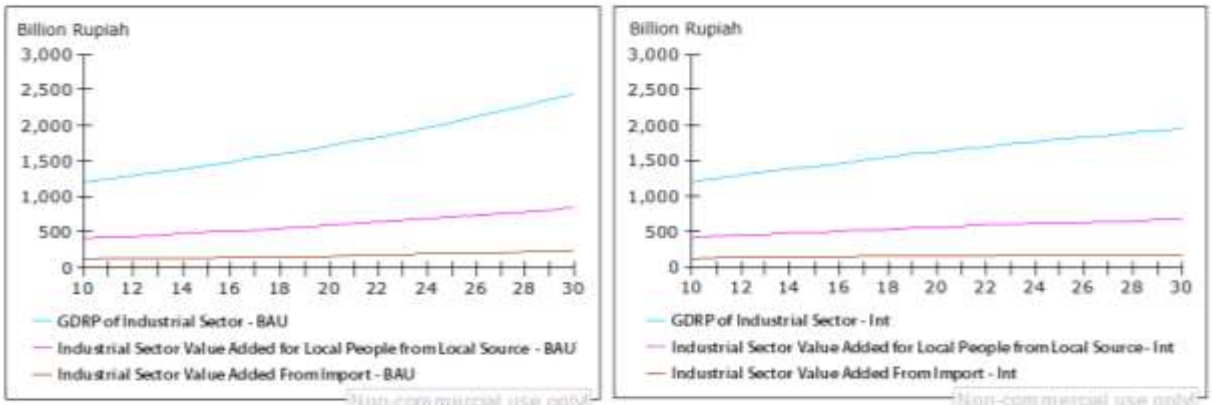

Figure 6. Results of the Intermediate Input simulation results on Industrial GRDP in West Papua.

9 Conclusions

The built system dynamics model in this study has successfully predict the GRDP obtained if West Papua incorporates EID to mitigate emissions from 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 exceed in emissions from its threshold if West Papua do not implement EID scenario through 2030. It is projected that the GHGs emissions under 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 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 external 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 Industrial Sector and achieve NDC target in 2030. Besides, the study recommends that 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 provincial government need to consider the economic contraction by taking into account climate mitigation activities, specifically 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 industrial sector. In addition, the future researches need to be enhanced to involve variables of environment and social in West Papua to in-depth explore its relationships with factor production of labor in industrial sector.

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IV.LAPORAN KEUANGAN

3.1. Surat Permohonan TASCA TAHAP II (Deliverable I) – PPLH Pengurus Lama

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor online peserta (2 hari), 50 peserta	700.000,00	70.000.000,00
2	Honor online grup intensif (2.5 hari), 9 peserta	400.000,00	9.000.000,00
	Total Honor		**79.000.000,00**

Penggunaan Anggaran TASCA TAHAP II (Deliverable II)

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor online peserta (2 hari), 35 peserta	700.000,00	49.000.000,00
3	Honor online grup intensif (5 hari), 15 peserta	400.000,00	30.000.000,00
	Total Honor		**79.000.000,00**

3.2. Surat Permohonan TASCA TAHAP II (Deliverable II) – PPLH Pengurus Baru

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor I Assisten + bantu Laporan (Puja Kenndy)	5.000.000,00	5.000.000,00
2	Honor I Koord (Hendri) + Laporan	15.000.000,00	15.000.000,00
3	Honor I Penanggung Jawab (Elen)	15.000.000,00	15.000.000,00
4	Honor I Tim PPLH (Ihwan Tjolli)	5.000.000,00	5.000.000,00
5	Honor I Tim Koord Ekonomi, Sosial dan Lingkungan (Rully N Wurarah, Ihwan Tjolli, Saraswati Prabawardani)	4.000.000,00	12.000.000,00

No	Kegiatan	Satuan (Rp)	Total (Rp)
6	Honor I Tim Model Ekonomi, Sosial dan Lingkungan (Frenly Wehantouw, Alderhard, Hendri)	3.500.000,00	10.500.000,00
7	Honor I Tim Data Ekonomi, Sosial, dan Lingkungan (Abdullah Tuharea, Jance M Supit, Kati Syamsudin)	3.500.000,00	10.500.000,00
	Total Honor		**73.000.000,00**

Penggunaan Anggaran TASCA TAHAP II (Deliverable II)

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor I Assisten + bantu Laporan (Puja Kenndy)	5.000.000,00	5.000.000,00
2	Honor I Koord (Hendri) + Laporan	15.000.000,00	15.000.000,00
3	Honor I Penanggung Jawab (Elen)	15.000.000,00	15.000.000,00
4	Honor I Tim PPLH (Ihwan Tjolli)	5.000.000,00	5.000.000,00
5	Honor I Tim Koord Ekonomi, Sosial dan Lingkungan (Rully N Wurarah, Ihwan Tjolli, Saraswati Prabawardani)	4.000.000,00	12.000.000,00
6	Honor I Tim Model Ekonomi, Sosial dan Lingkungan (Frenly Wehantouw, Alderhard, Hendri)	3.500.000,00	10.500.000,00
7	Honor I Tim Data Ekonomi, Sosial, dan Lingkungan (Abdullah Tuharea, Jance M Supit, Kati Syamsudin)	3.500.000,00	10.500.000,00
	Total Honor		**73.000.000,00**

Dana Masuk Deliverables II Tahap II : Rp 79.500.000,00
Dana Keluar Deliverables II Tahap II : Rp 73.000.000,00
Dana sisa : Rp 6.500.000,00

3.3. Surat Permohonan TASCA TAHAP II (Deliverable III) – PPLH Pengurus Baru

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor Final Asisten (bantu Laporan)- Puja Kenndy	5.000.000,00	5.000.000,00
2	Honor II (Koordinator) + 4 Laporan	20.000.000,00	20.000.000,00
3	Honor Final (Koord. Ekonomi)	3.000.000,00	3.000.000,00
4	Honor Final (Koord. Lingkungan)	3.000.000,00	3.000.000,00
5	Honor Final (Koord. Sosial)	3.000.000,00	3.000.000,00
6	Honor Final (Model ekonomi, lingkungan dan sosial) – Frenly	2.500.000,00	7.500.000,00
7	Honor Final (Data ekonomi, [illegible]	2.500.000,00	7.500.000,00
	Total		**49.000.000,00**

Penggunaan Anggaran TASCA TAHAP II (Deliverable III)

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Honor Final Asisten (bantu Laporan)- Puja Kenndy	5.000.000,00	5.000.000,00
2	Honor II (Koordinator) + 4 Laporan	20.000.000,00	20.000.000,00
3	Honor Final (Koord. Ekonomi)	3.000.000,00	3.000.000,00
4	Honor Final (Koord. Lingkungan)	3.000.000,00	3.000.000,00
5	Honor Final (Koord. Sosial)	3.000.000,00	3.000.000,00
6	Honor Final (Model ekonomi, lingkungan dan sosial) – Frenly	2.500.000,00	7.500.000,00
7	Honor Final (Data ekonomi, [illegible]	2.500.000,00	7.500.000,00
	Total		**49.000.000,00**

Dana Masuk Deliverables III Tahap III : Rp 53.000.000,00
Dana Keluar Deliverables III Tahap III : Rp 49.000.000,00
Dana sisa : Rp 4.000.000,00

3.4. Surat Permohonan TASCA TAHAP II (Deliverable IV) – PPLH Pengurus Baru

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Institution Fee	26.500.000,00	26.500.000,00
2	Management fee (Ketua PPLH)	17.500.000,00	17.500.000,00
3	Management fee (Koordinator TASCA)	17.500.000,00	17.500.000,00
4	Keperluan PPLH	2.000.000,00	2.000.000,00
	Total		**63.500.000,00**

Penggunaan Anggaran TASCA TAHAP II (Deliverable IV)

No	Kegiatan	Satuan (Rp)	Total (Rp)
1	Institution Fee	26.500.000,00	26.500.000,00
2	Management fee (Ketua PPLH)	17.500.000,00	17.500.000,00
3	Management fee (Koordinator TASCA)	17.500.000,00	17.500.000,00
4	Keperluan PPLH	2.000.000,00	2.000.000,00
	Total		**63.500.000,00**

Dana Masuk Deliverables II Tahap IV : Rp 53.000.000,00
Dana sisa Deliverables II (Tahap II) : Rp 6.500.000,00
Dana sisa Deliverables II (Tahap III) : Rp 4.000.000,00
Total Dana : Rp 63.500.000,00

V.PENUTUP

WRI Indonesia dan PPLH melalui program ‘Melacak dan Memperkuat Aksi Iklim’ (TASCA) Tahap II berupaya untuk mendukung pemerintah provinsi Papua Barat dalam melacak kemajuan aksi iklim serta potensi kontribusi daerah terhadap pemenuhan komitmen iklim nasional melalui pelatihan permodelan system dinamik guna membuat model Pembangunan Rendah Karbon di Provinsi Papua Barat. Harapannya model tersebut dapat memberikan sumbangsih terhadap penyusunan dokumen Perencanaan Pembangunan Rendah Karbon Provinsi Papua Barat.