projects in Viet Nam.- Decision No. 24/2014/QD-TTg dated 24 March 2014 of the Prime Minister on support mechanism for development of biomass power projects in Viet Nam.

- Decision No. 31/2014/QD-TTg dated May 05th, 2014 of the Prime Minister on supporting mechanisms for development of power generation projects using solid waste in Viet Nam.
- Decision No. 2068/QD-TTg dated November 25th, 2015 of the Prime Minister approving the development strategy of renewable energy of Viet Nam by 2030 with a vision to 2050. One of the objectives of the strategy is to develop and utilize renewable energy sources in a way that contributes to fulfilling the objectives of sustainable environment and development of green economy
- Decision No. 428/QD-TTg dated March 18th, 2016 of the Prime Minister approving the Revised Master Plan of National Power Development for the period of 2011-2020 with the Vision to 2030 (Master Plan VII-revised), in which the proportion of renewable energy (namely small hydropower, wind power, solar power, biomass power) in total electricity output is projected to reach 6.5% by 2020, 6.9% by 2025 and 10.7% by 2030.
- Decision No. 13443/QD-BCT dated December 08th, 2015 of the Minister of Industry and Trade approving the Green Growth Action Plan for the industry and trade sector for the period of 2015-2020, which concretizes the key tasks in the industry and trade sector to implement the objectives and mandates of the National Green Growth Strategy and National Green Growth Action Plan for the period of 2014-2020.
- Decision No. 11/2017/QD-TTg dated April 11st, 2017 of the Prime Minister on mechanisms for encouragement of development of solar power in Viet Nam.
- Decision No. 13/2020/QD-TTg dated April 6th, 2020 of the Prime Minister on mechanisms for encouragement of development of solar power in Viet Nam.

Analysis the long-term impact of low carbon transport policy in Jakarta city

Case study: electrification of vehicles and biofuel program

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Abstract

Under the Paris Agreement, the Jakarta city government as non-state actor is preparing the Indonesia first long-term strategy at sub-national/province level through the Low Carbon Development Strategy (LCDS) to achieve Jakarta's target 2050. The strategy was developed based on the existing masterplan and future development plan. The article aims to analyse the impact of strategy on public transport development, electrification of vehicles and biofuel program and its impact on GHG emission in Jakarta 2050. Two scenarios of business as usual associated GHG emissions without considering mitigation effort while countermeasures scenarios were developed to envision pathways to achieve low carbon city. We used a non-linear programming model ExSS GAMS v 23.3 to analyse the impact of transformative actions on transport sectors in Jakarta city. The use of alternative biofuel from the biodiesel for commercial trucks provide a large GHG emission reductions in the mid-term while the electrification of vehicles and improvement of fuel efficiency of public transport provide large GHG emission in the long-term. The massive developments of public transports supported by urban infrastructures such as pedestrian walkway encourages the modal shift from private vehicles, however, the impacts on GHG emission relatively small due to large share of travel demand by private vehicles. To maximising the impact of electrification of vehicles, upstream policy on renewable energy in necessary and combine with the downstream policies to increase diffusion of electric vehicles. A complimentary policies and strategies on travel demand managements is needed to increase the modal shift from private vehicles to public transport in Jakarta city.

Keywords: Low carbon transport, Jakarta city, electric vehicle, biofuel, modal shift

1. Introduction

Under the Paris Agreement, the Indonesian government begins to prepare a long-term strategy (LTS) to achieve GHG emissions reduction target in 2050. In order to contribute to GHG emissions reduction of 29% (unconditional target) and 41% (conditional target) below the baseline, the energy sector should reduce its GHG emissions level in 2030 by 314 Mton CO_2e and 398 Mton CO_2e (Indonesia

NDC, 2016). To achieve this level, the GHG emissions is estimated become 5.63 ton CO_2e per capita in 2030 or equal to almost three times compare to the emission per capita in 2010. In the long-term, Indonesia has the potential to deeply reduce GHG emissions from the energy sector to about 1.31 ton CO_2e per capita in 2050, equal to 0.69 of the emission level per capita in 2010 (Siagian, 2017). The Indonesian government begins to prepare a long-term GHG emissions reduction target (2050) involving various stakeholders, state and non-state actors. Action and inactions by central, regional and local government will give significant impacts on climate mitigation actions at city level (Heidrich et al, 2016; Reckien et al, 2015). The government of Indonesia already developed roadmap implementation of Nationally Determined Contributions (INDC) in 2018 (Masripatin et al, 2018). Several local governments, as a non-state actor, are actively develop local action scenarios attempting to reduce their GHG emissions and contribute to the NDC.

The Jakarta city government as one key non-state actor is pioneering the Indonesia's first long-term strategy at sub-national/province level through the Low Carbon Development Strategy (LCDS) to achieve Jakarta's target 2050. The local government committed to implement GHG mitigation strategies through the governor regulation of DKI Jakarta no 131/2012 on local action plan on the GHG mitigations actions (RAD GRK) and set an ambitious climate change strategy reducing GHG emission by 30% by 2030 using a 2010 baseline (Dewi et al, 2016). Considering its emissions sources, geographical situation of urban coastal city and built environment conditions, the energy sector accounted for 89% of total GHG emission of Jakarta (Dewi et al, 2016). Thus, the Jakarta's mitigation actions also explicitly heavily rely on energy sector about 35 Mtoe CO_2 (Diyarni, 2018). While waste sector and agriculture forestry and other land use (AFOLU) expected to contribute about 8% and 2% respectively. The long-term strategy (LTS) of Jakarta city will still focus the attention on energy, power and waste sectors, while a few concern on AFOLU sectors. Within the energy sector, transportation sector account for about a quarter of energy-related CO_2 emission globally (IPCC, 2018; International Energy Agency, 2020). In the Jakarta case, transportation contribute about 19% of total GHG emissions in Jakarta city (Diyarni, 2018). Decarbonisation of Transport sector is key component on mitigation actions in heavily dense urban area as like as Jakarta city. At present, more than two-thirds of transportation emissions are from road travel (Sims R et al, 2014), but air travel has the highest emission intensity and is responsible for an increasingly large share. The strategies to reduce GHG emissions from transportation includes: avoid unnecessary travel, modal shift (shifting to lower-carbon option, like rail); improve vehicle efficiency and fuel substitution to alternative fuels and electrification (Sims R et al., 2014).

A low carbon scenario for the transport sector should ideally be a balanced and context appropriate combination of 'Avoid- Shift-Improve' (ASI) strategies that applicable uniformly across passenger and freight movement (Hidalgo and Huizenga, 2013). In the urban context such as Jakarta, the mitigation actions from the road transport sector, both passenger and freight, offer the largest magnitude of mitigation potential (Taptich, et al, 2016) and GHG emissions reduction may came from direct actions or indirect actions (Gomi, 2011). For example, transportation infrastructures can lock-in high emissions from urban area due to their very long lifespans and increasing the demands as impact of economic and demographic growth especially in the developing country context while on the contrary, compact city development may avoid (A) unnecessary trip (Romito, 2019). The intensive improvement of public transport infrastructures such as Mass Rapid Transit (MRT); Light Rail Transit (LRT), Bus Rapid Transit (BRT), non-motorized transit (NMT) may encourage the modal shift (S) from private vehicle to public transport which contribute to the reduction of GHG emissions. Those infrastructures development stand as the intersection between development goals, improve efficiency and competitiveness of city and climate change imperative. The other direct actions focusing on the improvement of vehicle performance and efficiency through a technology interventions such as fuel switching from fossil fuel to electric vehicles or biofuel (biodiesel) which is in line with national government programs in Indonesia may reduce fossil fuel consumption and GHG emissions (Nugroho, 2020). This article aims to analysis those above initiatives as long-term strategies initiated by Jakarta's government in collaboration or synergy with national government and other international cooperation initiatives and its contribution to achieve mid and long-term emission reduction target of Jakarta's government. To do so, this research apply an integrated assessment model (IAM) non-linear programming model ExSS using GAMS v 23.3. The back casting approach applied through the developing sets of desirable goals/targets in the future and explore the way to achieve the target. The GHG emissions in 2010 was used as baseline to estimate future situations or conditions of the targeted the impacts in mid-term (2030) and long-term period (2050). Projection of future scenarios was calculate based on business as usual (BaU) and counter measures (CM) scenarios. The BaU scenario envisions future development paths on transport sectors and its GHG emissions without considering mitigation efforts. The mitigation scenarios developed to envisage various transformative actions and programs on transport sector to achieve low carbon city in Jakarta city. The transformative actions at the local level focusing on modal shift (S) from private vehicle due to intensive and massive development of public transport and non-motorized transport infrastructures provide a large opportunity to reduce GHG emissions in the long-term period. The action the implementation of national program to improve combustion engine (I) based on mandatory of fuel switching to biofuel for freight (commercial trucks) gave larger opportunity to reduce GHG emission in a short and medium term on transport sector in Jakarta city. While the other improvement on technology initiated through electrification of vehicles (public transport and private vehicles) by local government may provide limited opportunity to reduce GHG emissions in the mid-term, but may significant in long-term. However the impacts could be maximising under the complimentary policy on renewable energy due to its dependency on the mix energy supply for the electricity which is still under responsibility and control by the national government.

The remainder of the article is divided into four sections. The next section reviews literature low carbon pathways and assessment. A third section describes the study location, actions plans and assumptions used in the assessment model. A fourth section presents key results. A final section concludes with a discussion of areas for future research.

2. Literature Review and Methodology

2.a. ASI approach for Decarbonizing Land Transport Sector

Global transport is the fourth largest source of GHG emissions in 2018, producing about 14% of total GHG emissions or about 23% of global energy-related CO_2 emissions (International Energy Agency, 2020). Transport greenhouse gas emissions trends have increased fast over the last two decades, and since 2010, the sector's trends have increased faster than for any other end-use sector, averaging +1.9% annual growth since 2000. The largest component of transport emissions and their main source is from the movement of passenger and freight in road transportation (6.2 Gt CO_2eq, 73% of total). Urban transport is responsible for about 8% of global CO_2emissions (3Gt CO_2 yr-1) (IEA 2012, Creutzig, 2016). Land-based transport is a crucial component of the urban mobility system, however decarbonization of land transport has been identified as key barrier because of its high cost of substituting energy-dense liquid fossil fuel (Kahn Ribeiro, S et al, 2012). This is because of the high energy density of fuels required for many types of vehicles, which constrains low-carbon alternatives, and because transport policies directly impact end-users and are thus more likely to be controversial. Low carbon technologies for land-based transport will be increasingly important to meet decarbonisation goals, as demand for these services will continue to grow in the future. The strategies can be categorized into avoid, shift and improve categories which constituting a simple analytical framework and well established in transport sector (Sims R et al, 2014). There have been also divergent developments for decarbonization efforts in transports sector focusing on the improvement (I) involving accelerating deployment of technologies that increase performance of vehicles and fuels (Gota, et al, 2015; Lutsey & Sperling, 2012). The adoption of alternative fuel (e.g., electricity, hydrogen, biofuels, and synthetic hydrocarbons/e-fuels) could support decarbonization and offers many potential climate benefits on the transportation sector (Chester and Horvath, 2012). On the road transport, electrification for light-duty vehicles are now commercially available and are likely to be more cost competitive in the near future. The light vehicle electro-mobility systems with high Technology Readiness Levels are likely to provide the major opportunity for the transformative scenarios toward the net-zero, especially where mainstreaming interventions include removing commercial barriers, facilitating markets and especially providing e-charging infrastructure facilities.

The Indonesian government strategies on low carbon transport have five focuses areas consists of: (a) transportation and interaction with land-use and spatial planning; (b) improvement on urban mobility and reducing urban traffic jam; (c) supply management; (d) the reduction of urban emission and air pollution; and (e) improvement on traffic safety. The next logical step in pursuing those goals and strategy has been task sub-national and municipal governments with their policies and climate mitigation action plans to reduce GHG emissions (Jaeger, 2015). Cities have increasingly been identify as important places for sustainability transitions and system innovation on climate issues (Frantzeskaki et al., 2017). The transition towards a climate compatible urban development and framing climate mitigation actions also involves two methodological challenges (a) the establishment of linkages between actions and outcomes (e.g. through a quantitative modeling approach) and (b) a way of objectively comparing the outcomes of different actions (Junghans, L., et al, 2018). The backcasting has been consider as one of the best method for realizing the transformation of technology and society toward sustainability (Vergragt, 2011). The desirable future GHG emissions reduction target already determined by the city government through the Governor Decree no 131/2012, then, looking backwards from that future (2030 and 2050) to the present in order to strategize and to plan how transport sector could contribute.

2.b. AIM Modeling ExSS

The quantitative modelling approach and policy analysis helps policy makers to understand the impacts of certain policy to achieve the desire goals of GHG emission reduction target to contribute to the NDC. To do so, we use the Asia-Pacific Integrated Assessment Model Extended Snapshot (ExSS) using GAMS v 23.3. The model relies on the framework of non-linear programming supported by various technical, economic and social parameters. The structure of the ExSS tool includes input parameters, exogenous variables and variables between modules as illustrated in figure 1. The population and economic developments are the main driving force of energy demand and, correspondingly GHG emissions. While scenario of development and choice of technology and type of fuel will determine the magnitude of energy demand and its associated GHG emissions. Based on the back casting approach, first, we developed sets of desirable goal and explore the ways to achieve it. It includes (i) setting of framework such as time period, environmental target and number of scenarios; (ii) collecting data for the baseline information i.e., socio-economic assumption; (iii) collecting data on the low carbon transport counter measures (CM); (iv) estimate future snapshots with and without countermeasures. The baseline year 2010 used in this study while future desired target will be 2030 (mid-term) and 2050 (long-term). The projection of future scenarios was develop based on business as usual (BaU) and mitigation/counter measures (CM) scenarios. The BaU scenario envisions development paths and the associated GHG emissions without considering mitigation effort. The mitigation scenario developed to envision the development paths to achieve low carbon city. The relationship between economic activity and energy sector development illustrated in Figure 2. Projection scenario for both, BaU scenario and mitigation scenario, uses the same socio-economic indicator assumptions (see Table 2)

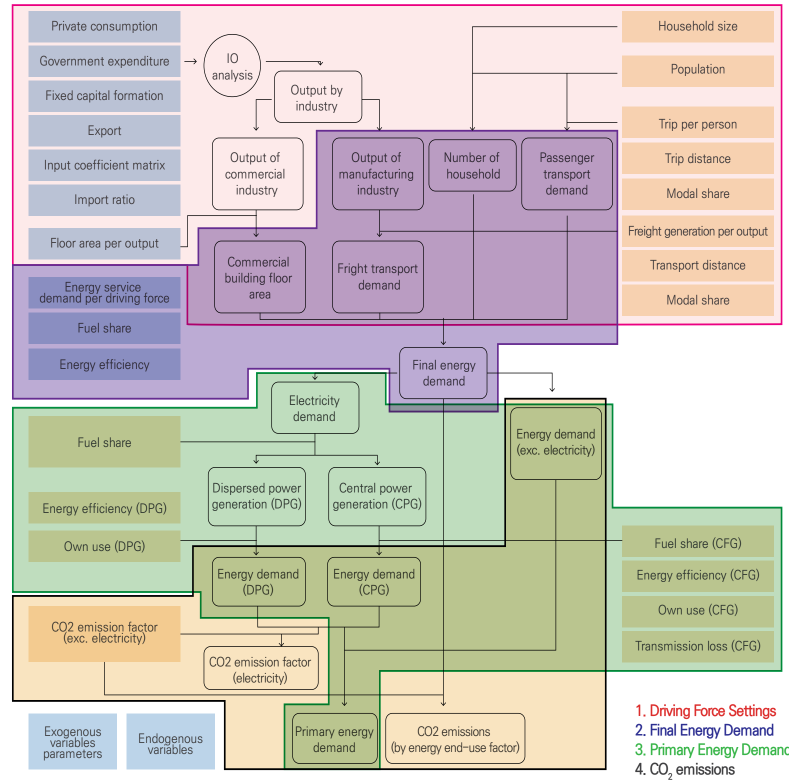

Figure 1. the Asia–Pacific Integrated Assessment Model Extended Snapshot (ExSS)

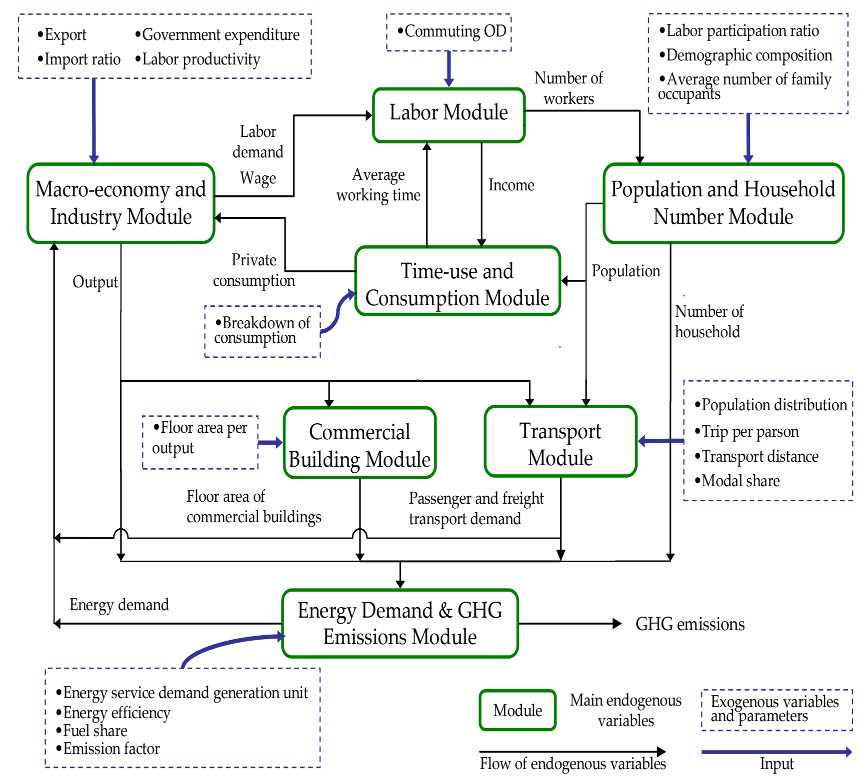

Figure 2. The relationship between economic activity and energy sector

3. Study Location, Transport Action Plans and Assumptions

3.a. Study Location

DKI Jakarta is the capital city of Indonesia with population more than 10.5 million in 2020 and has grown at 1.15% annual change since 2015 (World population review, 2021). It is the biggest city in the country and one of the most populous urban agglomeration in the world and largest city in Southeast Asian region. It is a metropolitan area with surrounding cities called as Jabodetabek stands for Jakarta, Bogor city, Depok city, Tangerang City and Bekasi. The metropolitan area of Jabodetabek has a population exceeds 30 million with a total land area of 4,384 square kilometres. While Jakarta city has 662 km^2 of land area and 6,977 km^2 of sea area. Jakarta and population density around 14,464 people per square kilometre.

Jakarta is an important alpha world city with major financial institutions, Indonesia Stock exchange, and corporate headquarters of numerous Indonesian companies and multinational companies. It is home for several Forbes Global 2000 companies, Fortune 500 Companies and other Union Companies significantly contributes to the country's economy. The city's GRP was about $483.4 billion USD and GDP around 396 trillion Rupiah (at constant price 2000) in 2010. The city accounts for 17% of national GDP. To support the urban mobility, the city heavily rely on private vehicles (cars and motorcycle). The share of public transport in Jakarta metropolitan area around 27% (ESCAP, 2017). The local government try to improve share of public transport through the various interventions by providing public transport infrastructures in collaboration with National Governments and others. The population growth, economic characteristics, and transportation condition has to lead climate change issues with GHG emissions level. The ambitions and commitment of the Jakarta's government on emissions reduction target in 2030 declared in the local regulation, governor decree no 132/2012 about local mitigation actions to reduce GHG emissions in Jakarta city. This commitment has been monitored and reviewed in order to response to the latest development in the national as well as regional level, particularly related to the GHG Emissions. The city government also enacted seven-point of Governor Instruction No 66/2019 on air quality control.

3.b. Transformative Actions on Low carbon transport in Jakarta city

Transport action plans in Greater Jakarta areas consists of several plans by National Governments and local governments. In the Jabodetabek region, the Greater Jakarta Transportation Masterplan (RITJ) 2018-2029 was approve through the presidential decree 55/2018. The transformative actions on low carbon transport currently being updated and revised to respond to the latest development in the national as well as regional level, particularly, which are related to the GHG Emissions. First, the city government are motivated to accelerate the implementation of air quality control to improve the better air quality. The detail actions were implemented through the seven-point of Governor instructions No. 66/2019. At this moment, the city heavily rely on private vehicles (cars and motorcycle) for urban mobility and the share of public transport in Jakarta metropolitan area around 27% (ESCAP, 2017). To improve the situations, the national government and local government developed various public transport infrastructure such as mass rapid transit, light rail transit and others (Table 1). The government also improve pedestrian and non-motorized transport facilities to encourage modal shift for walking and cycling within the city.

In summary, the decarbonization plan mainly consist of three main Avoid-Shift-Improve approaches. The detail of each approached as follows:

(a) Avoid: TOD, land-use planning and city developing planning especially along the corridor of new railway development (Mass Rapid Transit (MRT) and Light Rail Transit (LRT)) and its stations. One of TOD model project was located in Poris Plawad in Tangerang City, one of neighbor city of Jakarta nearby Jakarta Airport in the western part of the city (Selenia EP, 2018)

(b) Shifting to Public Transport and Non-Motorized To encourage modal shift, national and local government build public transport infrastructures aggressively. The first phase of Mass Rapid Transit was built since 2013 and start to operate in March 2019.

(c) Improve (Shift to Electricity and Biofuel) Electrification of vehicles in Indonesia started by Low carbon emission program as the initial steps (Schroder, et al, 2021) and followed by President regulation to promote BEV (2019). The national policy aims to establish EVs hub; create the link of EVs and Battery Production (Schroder et al 2021). The government also aims to promote the local EV Manufacturing and export EVs to Australia and other ASEAN countries. The national policy also announced EV adoption target such as target EV market share (Li & Chang, 2019). The national government have set a target of EV market share about 20% of domestic vehicle sales by 2025 and 25% by 2030. In the long-term, it is expected to have BEV stock equal to 4.2 million vehicles & 10,000 units of charging stations by 2050 (Schroder, 2021). In response to the national policy of electrification of vehicles, the local government of Jakarta decided to play as an early adopters of the BEVs especially for the public transport fleets, Trans Jakarta. The transportation agency of Jakarta city released the decree no 120/2019 to assigned Trans Jakarta to conduct trial run of EV buses in Jakarta. The company also developed a roadmap for electrification of their fleets up to 2027. The ministry of energy and mineral resource (MEMR) released the policy on the provision of electricity charging infrastructure for batter-based electric motor vehicles aims to accelerate the programs. The international cooperation and technical assistant from international organization such as UNEP CTCN and C40 were implemented to support Jakarta's transition to electromobility. A comprehensive study on electric vehicles by the ministry of Industry and ministry of research and higher education of Indonesia together with Toyota Indonesia and several universities show the key findings on fuel efficiency and CO2 reductions from EVs.

Due to the large potential for bioenergy, the Indonesian government set up a policy on the production and use of biofuels and, in particular, biodiesel produced from the refining palm oil. The biodiesel blending program was first introduced in 2015 through MEMR Reg No. 12, which targeted 20% blending (B20) by 2016 for transportation and industrial consumption. In September 2018, the government expanded the subsidy scheme to non-Public Service Obligation (PSO) organizations through Presidential Regulation No.66/2018. The program is expended and also mandatory for other sectors such as mining, and other diesel-using industries. There is also an intention to further increase the target for blending for 30% biodiesel blending (B30) and 20% ethanol (E20) blending from 2025 onwards. The intention of increasing the blending mostly due to the oversupply of domestic market palm oil caused by the decreasing of the overseas market especially in the European region due to recent decision of the EU on biofuels (Suharsono et al, 2019). This exogenous shock reduces the overseas demand and the biofuel policy is therefore designed to provide an additional domestic market. The biofuel policy also aims to reduce diesel fuel imports (and thereby boost the trade balance) (Suharsono et al, 2019) and to reduce the fiscal cost of subsidizing diesel.

3.c. Basic assumption in the Assessment Model

The population of Jakarta city will continue to grow with an annual rate 1%. Total population in 2030 and 2050 are 1.17 times and 1.24 times compare to the reference in 2010 (Table 2). In parallel, number of household will also increase up to 1.17 times in 2030 and 1.3 times in 2050. In the long-term, increasing rate of household slightly higher due to the decreasing of family size in the household compare to the reference in 2010. On the socio-economic indicator, the GDP assumed to be increased on average 5.7% per year from 2010 to 2050. As result, the macro-economic indicators such GDP and Gross output will increase almost 3 times in 2030 and more than 9 times in 2050. The GDP per capita will also become double in 2030 and increase 9 times in 2050 compare to 2010. Looking at the economic sector, tertiary industry (commercial and services) will be dominant in the future. It will followed by secondary industry such as manufacturers and constructions industry and the rest will be primary industry.

Source: Authors compilations

Category Policy measures	Expected Outcome	Target of Implementation	Indicator in Modeling
A.Shift			
Investment in public transport infrastructures (Mass Rapid Transit; Light Rail Transit)	Shift from private vehicles to public transport	a.MRT 1st Corridor (south-north) phase 1: Already in operational stage since March 2019 b.MRT 1st Corridor phase 2: 2025 c.MRT 2nd Corridor (East-West): 2027 d.LRT Jabodebek (intercity with peripheral): 2022 e.LRT Jakarta (inner city) – Corridor 1 Phase 1: Already in operation since December 2019	Increasing the modal share of public transport mode and reduce modal share of travel demand by private vehicle around 55.48 in 2030 and about 53.63 in 2050 (Table 3)
Investment in Non-motorized transport (NMT) facilities	Shift from private vehicles or motorized vehicles to non-motorized transport	Pedestrian: 2600 km pedestrian network. Progress: 2017: 78 km; 2018: 118 km; 2019: 67 km; 2020: 95 km. Bicycle Path: Progress: Trial route 63km in 2019; 128 km in 2020	Increase the modal share of non-motorized and cycling around 0.4% in 2030 and 0.8% in 2050 (Table 3)
B.Improve			
Fuel efficiency standards, fuel efficiency incentives; taxes on fuels; subsidies for ev and hybrid vehicles	Switch from gasoline or diesel vehicle to electric vehicles; 2-3 wheelers; smaller cars (improve);	National target EV market share: 20% of domestic vehicle sales by 2025 and 25% by 2030. 4.2 million vehicles & 10,000 units of charging stations by 2050 (Schroder, 2021)	Penetration of EVs in the vehicle population about 17% in 2030 and 100% in 2050
	Switch from Diesel Bus to EV buses for the fleets of Trans Jakarta BRT	EV Bus. Replacement program will start in 2021 and will finish completely 100% in 2027 (Nugroho, 2020)	Rejuvenation of public transport and flue gas emission testing. Penetration of best available technology around 18% in 2030 and 75% in 2050.
	Fuel Switching from regular diesel to Biofuel (Biodiesel) for commercial trucks	B30: 2020 B50: 2030 B100: will be achieved in 2045	Ratio of Biofuel in the Market, around 50% (B50) in 2030 and 100% (B100) in 2050.

Table 1. Summary of Transformative Actions on Transport Sector in Jakarta

Note: Data as input parameters for ExSS Modeling

	Unit	2010	2030	2050	2030/2010	2050/2010
Population	Persons	9,640,400	11,310,000	11,914,751	1.17	1.24
No. of households	Households	2,416,000	2,834,000	3,135,000	1.17	1.30
GDP	mil. Rp	1,075,761	3,073,233	9,856,274	2.86	9.16
Gross output	Bil.Rp	2,309	6,608	21,193	2.86	9.18
Primary industry		70.481	194.860	624.944	2.77	8.86
Secondary industry		958.496	2,737	8,777	2.85	9.16
Tertiary industry		1,280	3,676	11,791	2.87	9.21
Gross capital ormation	mil. Rp	136,947	418,655	1,342,683	3.06	9.80
Export	mil. Rp	473,891	1,135,113	3,640,460	2.39	7.68
Import	mil. Rp	704,743	2,166,537	6,948,378	3.07	9.86
Transport demand						
Passenger transport	bil.Pass-km	84.328	259.360	303.704	3.08	3.60
Freight transport	bil. Ton-km	2.943	13.440	43.104	4.57	14.65

Table 2. Socio-economic indicators in DKI Jakarta

3.d. Future Low Carbon Transport Scenarios

Scenarios are used to envision the direction of future visions to achieve low carbon development goals toward 2050, i.e., Business as Usual (BAU) scenario and low carbon scenario (CM). We use the similar assumptions on the basic socio-economic indicators in Table 2. While the specific conditions on transport sector are associated with the transformative actions on transport sectors (Table 1). The total passenger demand around 84,328 million-passenger kilometer in 2010 and mostly dominated by private vehicle (62.85%). The data in 2015 shows the passenger demand increased 1.9 times while the share of private vehicle decreased about 5%. The population and economic development of the city will increase the demand around 3 times in 2030 and 3.6 times in 2050 compare to 2010. The massive developments of urban public transport infrastructures and other transformative actions in Jakarta and surrounding areas is expected to increase the share of public transport (road and rail) about 7% in 2030 and around 9% in 2050. The mode share of non-motorized transport is also expected to increase around 0.41% in 2030 and about 0.8% in 2050. Public transport rejuvenation through the technology interventions and switching to electric vehicles will also reduce GHG emissions.

It is assumed in the modeling, the penetration rate of electric vehicle will be around 18% in 2030 and around 75% of private vehicle in 2050 while 100% of public buses will use electric vehicle since 2030 (Table 1).

The freight transport increase 1.75 times in 2015 from the reference data around 2,944 million ton-km in 2010. The freight transport will also rise rapidly and even faster than passenger transport. One of the main reason is due to shifting of industry activities to the tertiary industries such as commercial and services that need a lot of support from the logistic and freight (Table 2). As result, we estimated rapid increase of freight around 4.6 times in 2030 and more than 12.7 times in 2050 compare to the reference year in 2010. There is limited transformative actions on the "avoid and shift" of freight transport and the decarbonization efforts will rely on the technology intervention through the improvement of the efficiency through the fuel switching from diesel to biofuel/biodiesel following the national government policies and strategies on bioenergy for transportation system. In the simulation model of freight transport, the modal share of road, railway and shipping were assumed will remain same while the penetration ratio of biodiesel used for commercial trucks will follow the mandatory program by national government.

Source: Authors calculation

No	Descriptions	2010	BAU		CM	
			2030	2050	2030	2050
A	Passenger Transport					
	Private Vehicle	62.85 %	58.44 %	58.42 %	55.48 %	53.63 %
	Public Transport – Road	26.32 %	31.88 %	31.86 %	29.51 %	28.63 %
	Public Transport – Rail	10.35 %	9.23 %	9.27 %	14.15 %	16.50 %
	Airline/Aviation	0.48%	0.45 %	0.45 %	0.45 %	0.45 %
	Non-Motorized	0.00 %	0.00 %	0.00 %	0.41 %	0.80 %
B	Freight					
	Road/Truck	47.46 %	47.46 %	47.46 %	47.46 %	47.46 %
	Railway	20.46 %	20.46 %	20.46 %	20.46 %	20.46 %
	Shipping	32.08%	32.08%	32.08%	32.08%	32.08%

Table 3. Summary of Transport Demand (Modal Share – %)

4. Result of Estimation and Discussion

In parallel with the economic development and population growth, the transport demand for both passengers and freight will continue to grow in Jakarta city and surrounding areas. The energy demand will continue to grow around 2.96 times (2030) and 5.62 times (2050) higher than the energy demand in 2010 about 5,743 Mtoe. Looking at the profile of energy use, transportation is the leading sector in 2010 while it will gradually shift to commercial sector in 2050 (IGES, 2019). As the main industrial activities will gradually shift to commercial and services (tertiary industry), the freight services also increase rapidly. The GHG emission from transport sector will increase 3.08 times (2030) and 3.89 times (2050) compare to the situation in 2010 about 7,535 Mton CO_2. The low carbon transport programs for passenger transport and freight transport may improve the final energy demand on transport sector in 2030 and 2050. Total potential saving from both passenger and freight transport will be around 1,656 Mtoe (2030) and 5,700 Mtoe (2050). It gave potential emission reduction about 10,055 Mton CO_2 (2030) and 9801 Mton CO_2 (2050). The potential reduction of low carbon transport will be decrease in 2050 due to the improvement and diffusion or penetration of advance technology on transport priori to 2050. While in contrast, the diffusion and penetration of low carbon technology is still limited, therefore, the migration from less efficient to the low carbon technology create a large scale GHG emission reduction in 2030.

The fuel switching program Biodiesel of commercial trucks on the freight transport demand will give significant reduction of GHG emission in 2030. The potential GHG emission reduction is estimated around 7,728 million ton CO_2e, while the rejuvenation and improvement of fuel efficiency of public transport will reduce GHG emission around 1,194 million ton CO_2e (Table 4). First, the freight demand increase rapidly and the penetration of biodiesel will achieve around 50%. However, in the long-run, the improvement of fuel efficiency of public transport will give more significant reduction of GHG emissions due to its penetration of best of available technology (75%) (Table 3). The emission reduction from the improvement of fuel efficiency of public transport and flue gas emission test will reduce around 5,542 million ton CO_2e (Table 4).

Electrification of private vehicle will potentially reduce GHG emissions up to 0.427 Mton CO_2e and 0.040 Mton CO_2e in 2030 and 2050, respectively (Table 4). The impact of electrification of private vehicles in 2030 is bigger due to the share of best available technology still very low (18%) in 2030. While in contrast, most of vehicle (75%) will use best available technology in 2050 and therefore, the electrification of vehicles give less impact on GHG emissions. A key to maximizing the impact on the reduction of GHG emission from the electrification of vehicle as climate change mitigation actions on Road Transport in Asia and the Pacific is to reduce the use of coal for electricity production. Power generation is the most important source of CO_2 emissions from BEV in Asia and the Pacific. The AP region relies heavily on coal-based electricity generation (IMF, 2021): coal comprises 60 percent of the region's generation mix, higher than the world average of 40 percent. Further, 90 percent of the region's CO_2 emissions from electricity generation originate from coal. Thus, ongoing plans to invest massively in coal-fired power plants do not bode well (IMF, 2021). The national government of Indonesia try to increase the share of new and renewable energy supply up to 31% in 2050 (Erdiwansyah et al, 2019). Beside the heavily rely on the electricity sources, the specific policies and strategies at the downstream areas also play an important role in determining the significant influence of electrification of vehicles.

Beside the decarbonization efforts through the technology interventions as mentioned in above paragraphs, the transformative actions and massive developments on providing public transport and supporting infrastructures such as pedestrian and walkway also provide potential GHG emission reductions in Jakarta city. The potential GHG emission reduction due to shifting from private vehicles to public transport and non-motorized about 0.703 Mton CO_2e in 2030 and 1.134 Mton CO_2e in 2050. Although the transport demand from the private vehicle will still above 50% in 2050 (Table 3), it gradually decreased compare to the situation in 2010. To increase the modal shift and reduce the share of transport demand from private vehicles, it should be complement with the other policies on traffic demand management such as parking policy, road taxation etc.

5. Conclusion and Way Forward

Transport sector is one of the main source of global GHG emissions & road transport for the movement of passenger and freight are the biggest contributors compare to other transport modes. Freight emissions are growing faster than passenger transport emissions, and future emission trajectories of urban transport will be determined in rapidly urbanizing Jakarta. The mitigation actions from the road transport sector, offer the largest magnitude of mitigation potential and there have been also divergent developments for decarbonization efforts specially focusing on technology interventions which have different technology readiness and commercialization levels. The adoption of alternative fuel (e.g., electricity, hydrogen, biofuels, and synthetic hydrocarbons/e-fuels) could support decarbonization and offers many potential climate benefits on the transportation sector (Chester and Horvath, 2012). Electrification for public transport and light-duty private vehicles include motorcycle are most promising on road

Source: Authors Calculation

No	Mitigation Actions on Transport	GHG emission reduction Mton CO2e	
		2030	2050
A	Passenger Transport		
1	Improvement fuel efficiency of public transport	1194	5542
2	Electrification of Private Vehicles	0.427	0.04
3	Modal Shift from Private to Public Transport & NMT		
3.1	BRT	0.110	0.184
3.2	MRT & LRT	0.162	0.195
3.3	Electric Train (Intercity commuter railway)	0.315	0.528
3.4	Non-motorized transport and Bicycle	0.116	0.227
B	Freight		
4	Substitution of Diesel to Biofuel/Biodiesel	7728	3080

Table 4. Summary of Decarbonization of Road Transport in Jakarta city 2030 and 2050

transport because it is now commercially available and likely to be more cost competitive in the near future. Second, the adoption of biofuel from the biodiesel produced from palm oil due to its large potential sources for bioenergy and exogenous shocks from the overseas markets may improve fuel efficiency and reduce GHG emissions from transport sector.

The case study in Jakarta city shows the transformative actions on low carbon transport through various actions on providing public transport infrastructure to encourage modal shift from private vehicles and utilization of alternative fuels (electricity and biofuel) helps to reduce GHG emissions in the mid and long-term. The use of biofuel from commercial trucks provide immediate impacts on GHG emissions while the improvement of fuel efficiency and electrification of public transport may give more significant impact in the long-term. To maximizing the impact of electrification of vehicle, complementary program on renewable energy in the upstream and providing additional supports in the downstream such as charging facilities. The charging infrastructure was most strongly related to electric vehicle adoption (Sierzchula, et al, 2014; Yao, et, al, 2020). The policies focused on early adopters and niche markets such as public transport companies would create complementary system effects that will lead to increased PEV market penetration and realization of intended societal benefits (Green, H.E., 2014). Bringing on board the local authorities and stakeholders strengthen the diffusion process of EV (Gordon, et al, 2012; Kunle, 2020). The GHG emission reduction from the modal shift from private vehicles to public transport as the results of massive development of public transport infrastructures in Jakarta city shows a promising mitigation actions on transport sector too.

The integrated assessment model (IAM) non-linear programming model ExSS using GAMS v 23.3 could be used to assess the GHG emission reduction in the mid and long-term. The result of the bottom-up approaches at the city level provide opportunities to reduce GHG emissions in the mid and long-term future pathways on low carbon transport and GHG emission at the local level. The top-down approaches could be combined with the top-down that could help to explore and identify more transformative and ambitious actions needed in order to achieve Net Zero target in 2050 on road transport sector in the Asia-Pacific Regions.

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