CTCN Technical Assistance

"Developing a power to gas masterplan in Lao PDR"

COUNTRY ASSESSMENT

INDUSTRIAL SECTOR ASSESSMENT

TRANSPORTATION SECTOR ASSESSMENT

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Global Environment Centre Foundation (GEC)

GEC

CTCN
UN Climate Technology Centre & Network

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LIST OF ABBREVIATION

AFOLU	Agriculture, Forestry and Other Land Use
BOL	Bank of Lao PDR
CNG	Compressed Natural Gas
COD	Commercial Operation Date
DEPP	Department of Energy Policy and Planning, MEM
DPC	Department of Planning and Cooperation, MEM
DOC	Department of Customs, MOF
DOT	Department of Transport, MPWT
EDL	Electricite du Laos
EDL-GEN	EDL-Generation Public Company
EGAT	Electricity Generating Authority of Thailand
ERIA	Economic Research Institute for ASEAN and East Asia
EV	Electric Vehicle
GHG	Greenhouse Gas
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
LGG	Lao Green Gas
Lao PDR	Lao People's Democratic Republic
LPG	Liquefied Petroleum Gas
MEM	Ministry of Energy and Mines, Lao PDR
MOF	Ministry of Finance, Lao PDR
MPWT	Ministry of Public Works and Transport, Lao PDR
MONRE	Ministry of Natural Resources and Mines
ODA	Official development assistance
PtG	Power-to-Gas
PEA	Provincial Electricity Authority, Thailand
SUV	Sport utility vehicle

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1 COUNTRY ASSESSMENT

1.1 Summary

The CTCN technical assistance "Developing a power to gas masterplan in Lao PDR" (hereafter called Lao Green Gas (LGG) Project) can contribute to an efficient use of CO_2 free energy by recycling an emission from industries. Besides this the project can utilize surplus electricity available in Lao PDR (this context is hereafter as Laos) to produce hydrogen/methane gas for industry consumption and vehicle use. The project requires energy data relating to production, consumption, export, import, and energy loss in Laos. We aim to assess the current and future country energy mix by sectors, particularly in industry and transportation in order to estimate potential energy use and emission produced. Moreover, an assessment of the potential of current and future electricity production, domestic electricity needs and export needs requires data based on electricity production in Laos, and related sectors to forecast an electricity consumption.

In Laos, the major electricity generation sources are hydropower plants, followed by solar power, charcoal exploitation, and biomass. Biomass production is essentially on bagasse. The imported fossil fuel is a main source of CO_2 emission. Cement factories and a coal thermal power plant also contribute to emission in CO_2. Thus, an identification of potential sites for capturing CO_2 for production of renewable and synthetic fuels is essential. Besides we can estimate CO_2 emission from vehicle use by investigating mileage and average fuel consumption.

Based on data from electricity generation and consumption, we can assess a production potential of green hydrogen and synthetic fuels. An assessment of energy needs from electricity, industry, and transportation sectors also helps us to estimate greenhouse gas (GHG) emission,

which after implementing the Power-to-Gas (P2G) technology is perceived to reduce GHG emission.

We have obtained data from three main sources: (i) a direct source from an official data published by Lao ministries, (ii) an indirect source from ministries' reports prepared by relevant agencies and international organizations, and (iii) other data source from surveys, journal articles, and reports that is an unofficial one.

(i) Direct source - official reports and websites from line ministries

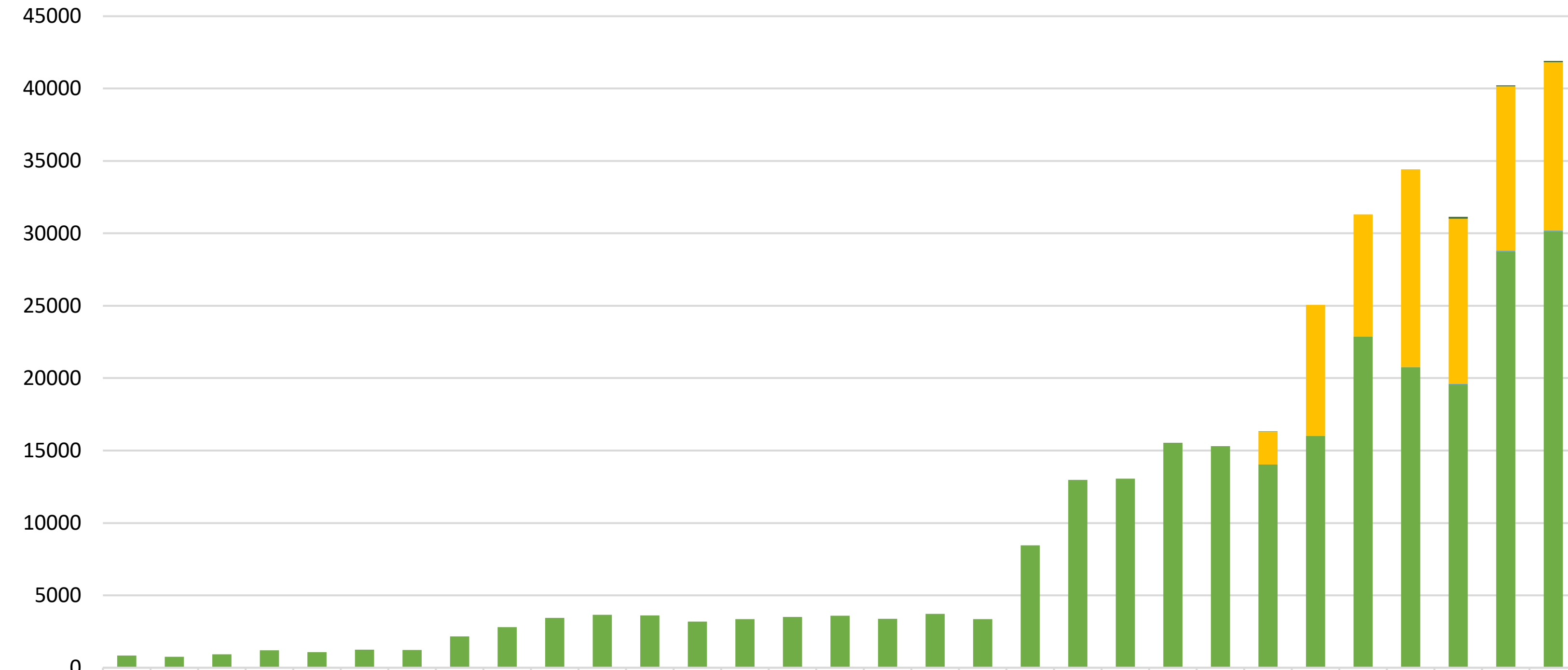
(ii) Indirect source - reports prepared by ERIA, and JICA that submitted to line ministries

(iii) Other source - domestic surveys, journal articles and reports

1.2 Basic information related to energy in Laos

1.2.1 Electricity generation

Figure 1: Electricity generation by source, 1991-2020 (GWh)



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Biomass (GWh)															
Coal (GWh)															
Solar (GWh)															
Hydro (GWh)	835	752	920	1,198	1,085	1,248	1,219	2,166	2,806	3,438	3,654	3,604	3,178	3,348	3,509

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
Biomass (GWh)								5	5	4				120	68	99
Coal (GWh)										2,259	9,068	8,454	13,656	11,406	11,355	11,624
Solar (GWh)											-	-	17	42	52	60
Hydro (GWh)	3,595	3,374	3,717	3,366	8,449	12,969	13,057	15,505	15,270	14,039	15,998	22,859	20,754	19,566	28,745	30,134

Source: A direct source from EDL, MEM, LSB

An indirect source from ERIA

Remarks: [a] We calculated 2016 coal data based on total electricity generation during 2016-2020 and 2017, 2018, 2019, 2020 actual coal-fired electricity generation data.

[b] Solar power plants operated since 2018.

[c] There is a missing data of biomass electricity generation in 2016, 2017, and 2018.

Electricity generation in Laos is meant for exportation to neighboring countries and to fulfil domestic consumption needs. A major source of electricity generation is hydropower and a coal-fired plant. There are a few solar power plants and biomass factories, which produce relatively small amount of electricity comparing to hydropower dams and a coal-fired plant. For domestic consumption, 90% of power is from hydropower dams, which are managed by EDL-GEN, EDL, and private power generation companies. A remaining 10% of domestic consumption is electricity imports. Currently, according to the DPC's report, there are 78 hydropower dams nationwide, with a capacity of 9,972 MW and expected to generate around 52,211 GWh of electricity annually.[1] In 2020, however, electricity generation from hydropower plants was 28,745 GWh, which increased from 19,566 GWh in 2019. It seems that power generation is overestimated.

Despite abundant electricity generation from hydropower dams, in 2015, the coal-fired plant (Hongsa Power) is in operation with the lignite mine power plant capacity 1,878 MW that generates around 2,259 GWh annually to export to Thailand. According to the MEM annual report, Hongsa power plant generated 11,355 GWh of electricity in 2020. The total electricity generation from Hongsa power plant was 53,939 GWh during 2016-2020 and expected to generate around 58,120 GWh during 2021-2025. The remains are solar energy and biomass power plant.

Table 1 displays an annual electricity generation from all types of power plants. It also shows domestic consumption, export, import, electricity surplus, and losses between 1991 to 2021. We obtained data between 1991-2015 from the 'Electricity Statistics Yearbook 2015 of Lao P.D.R'[2] by DEP, MEM. Data between 2019-2021 refers to the '2020 Annual Report of MEM'[3].

[1] DPC (2021). Report No. 288/MEM.DPC, 15 March 2021. [Lao language]
[2] DEPP (2015). Electricity Statistics Yearbook 2015 of Lao PDR.
[3] MEM (2020). The 2020 MEM Annual Report. [Lao language]

For electricity of 2016, 2017, and 2018 was obtained from various sources such as EDL[4], LSB[5], MEM[6], and ERIA[7]. [8]

[4] EDL (2019). The 2019 Electricity Statistics.
[5] LSB (2019). The 2019 Statistical Yearbook.
[6] MEM (2020). The 8th 5-Year Energy and Mines Development Plan and the 9th 5-Year Energy and Mines Development Plan. [Lao language]
[7] ERIA (2018). Energy Demand and Supply of the Lao People's Democratic Republic 2010-2018. MEM, Lao PDR.
[8]

Table 1: Electricity generation, consumption, export, and import (GWh)

Year	Total Generation [1]	Domestic Consumption [2]	Export* [3]	Import [4]	Energy Surplus [5]	Energy Losses of Distribution [6]	Energy Losses of the Whole System [7]
1991	835	221	563	35	86	N/A	N/A
1992	752	253	460	41	80	N/A	N/A
1993	920	265	596	48	107	N/A	N/A
1994	1,198	280	829	57	146	N/A	N/A
1995	1,085	338	676	77	149	N/A	N/A
1996	1,248	380	792	88	164	N/A	N/A
1997	1,219	434	710	102	176	N/A	N/A
1998	2,166	513	1,614	142	181	N/A	N/A
1999	2,806	566	2,229	172	184	N/A	N/A
2000	3,438	640	2,793	180	186	N/A	N/A
2001	3,654	710	2,871	184	256	N/A	N/A
2002	3,604	767	2,798	201	240	N/A	N/A
2003	3,178	884	2,285	229	239	N/A	N/A
2004	3,348	903	2,425	278	298	N/A	N/A
2005	3,509	1,007	2,506	330	323	19.32	N/A
2006	3,595	1,114	2,487	631	333	17.86	N/A
2007	3,374	1,298	2,230	793	810	15.30	N/A
2008	3,717	1,916	2,315	845	330	13.70	N/A
2009	3,384	2,258	1,921	1,175	362	11.98	N/A
2010	8,449	2,441	6,647	1,210	571	10.78	N/A
2011	12,980	2,556	10,668	904	649	10.14	N/A
2012	12,760	3,075	10,363	1,329	948	10.32	N/A

2013	15,512	3,381	12,494	1,272	907	12.02	N/A
2014	15,270	3,791	11,936	1,559	1,106	8.89	8.89
2015	16,501	4,239	10,842	2,050	2,565	10.20	7.12
2016	25,066	4,660	19,650	788	1,544	13.41	9.21
2017	31,550	4,966	24,900	431	2,115	12.77	8.75
2018	34,410	5,417	26,784	301	2,511	12.28	8.34
2019	31,134	6,960	24,303	1,345	1,216	12.10	7.77
2020	40,219	7,786	32,745	1,411	1,176	N/A	N/A
2021**	41,917	9,021	33,401	1,117	612	N/A	N/A

Source: A direct source from EDL, MEM, and LSB

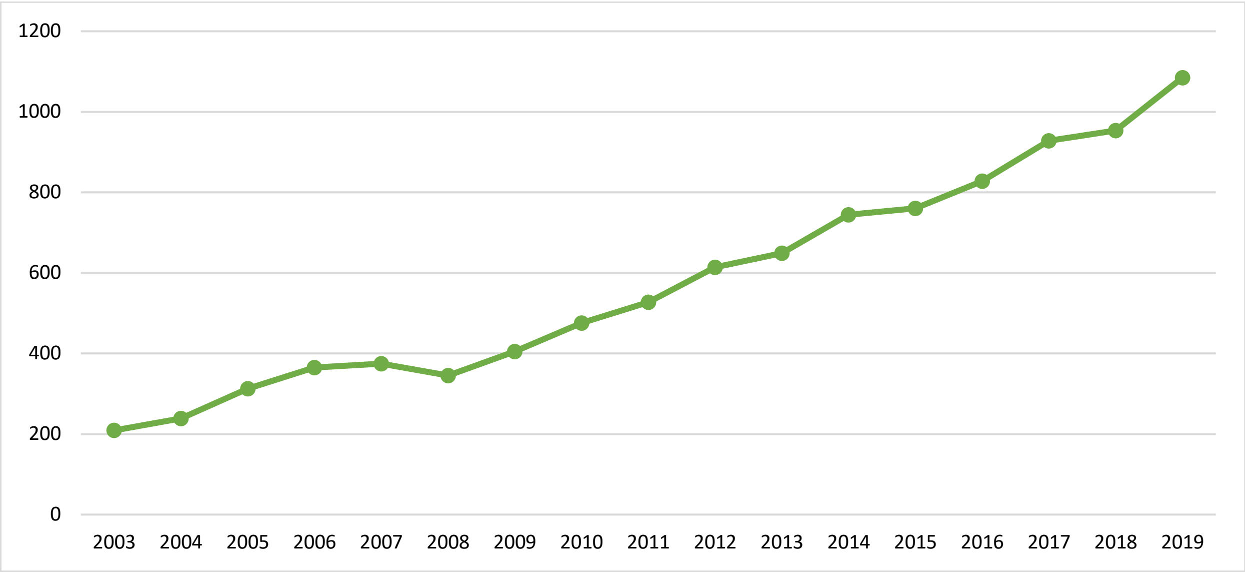
An indirect source from ERIA

Remarks: * Includes EDL and IPPs, ** MEM estimation, Total electricity generation consists of hydropower, coal-fired power, solar power, and biomass. During 1991-2012, hydropower dams were sole electricity generators in Laos. There was a small amount of electricity produced by biomass factories in 2013 and 2014. Despite major hydropower dams such as Nam Theun 2, Xayabouly, Sepien-Senamnoy, Theun-Hinboun, Sekaman 1, Nam Ngum 2, Nam Ngiep 1, Houyho, and other hydropower dams under EDL, which produce electricity for export; the Hongsa Lignite Power Plant has exported electricity mainly to Thailand since 2015. For import, Laos imports electricity from Thailand (Electricity Generating Authority of Thailand (EGAT) and Provincial Electricity Authority (PEA)), Vietnam and China. Domestic consumption is summed of residential, commercial, industry, government office, and others. Electricity surplus is the sum of the production and import data minuses the export data and domestic consumption. It does not include transmission and distribution losses in the calculation.

There are two main types of energy loss: (i) technical loss, (ii) non-technical loss. A technical loss refers to the losses that occur within the distribution network due to the cables, overhead lines, transformers, and other substation equipment that used to transfer electricity. In addition, it occurs due to transmission distance between electricity source and destination. A non-technical loss refers to conveyance errors when electricity is consumed but not correctly recorded. As shown in table 1, column [6] displays electricity loss of distribution in the whole country and column [7] displays electricity loss of the whole system distribution.

Note that data of hourly surplus electricity load profile is not available. Moreover, there is no publicly disclosed official data concerning levelized cost of electricity for hydropower, solar photovoltaic (solar PV), and wind power.

Figure 2: Electricity domestic peak demand in Laos, 2003-2019 (MW)

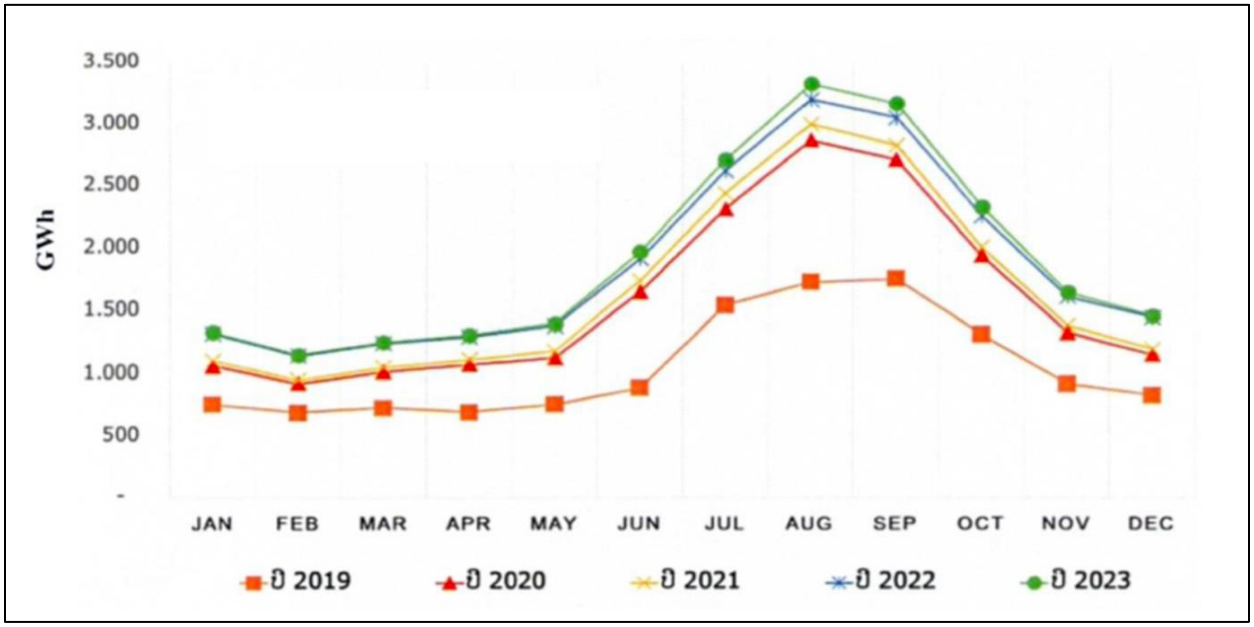


Source: A direct source from EDL and MEM

1.2.2 Seasonality of Electricity Generation

Figure 3 shows the transition of the change in the monthly electric power generation from 2019 to 2023 originating from the power plants for the domestic Laos market as per the DEPP report (MEM/No. 385). Figure 4 shows the monthly domestic electric power supply and demand, which is the supply and demand of EDL system in 2019.

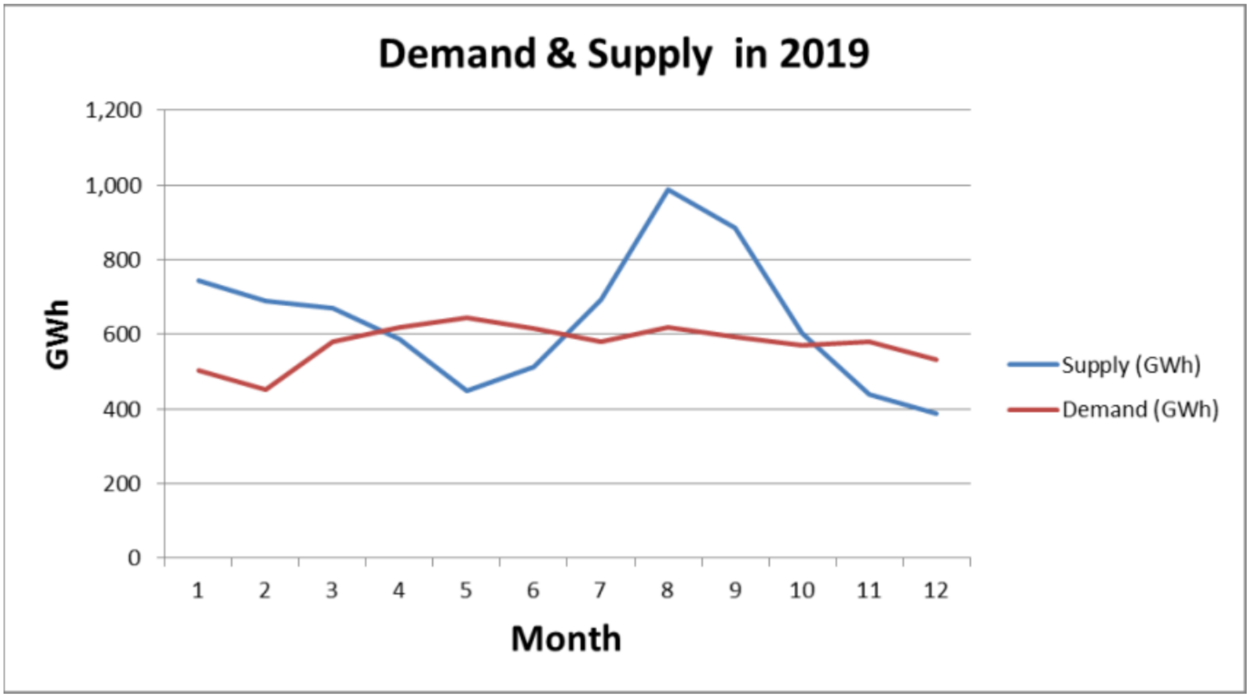
Figure 3: Forecast of Seasonal Changes in Power Generation in 2019 to 2023, (GWh)



Source: Hitachi Zosen Report (2019)[9] and MEM

[9] Hitachi Zosen Report (2019). International Demonstration Project on Japan's Energy Efficient Technologies. Survey of the requisites and compatibility of the demonstration. Demonstration of the Hydrogen/Methane production system from unused electricity in Lao PDR.

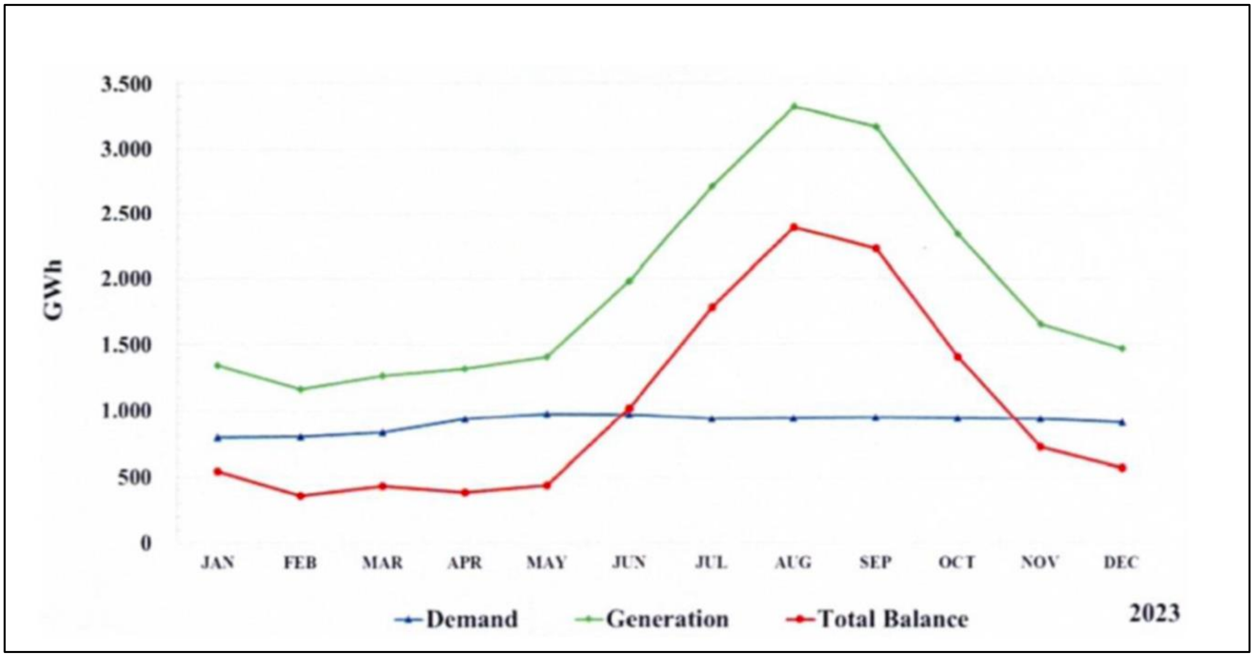
Figure 4: Seasonal Changes in Demand and Supply in 2019



Source: DEPP (2021)[10]. Noting that this amount of electricity generation in this figure supplies to EDL system only (2019).

[10] DEPP (2021). Challenges and Discussion on Energy and Mines Sector. [Lao language, unpublished document].

Figure 5: Forecast of Seasonal Changes in Demand, Generation, and Balance in 2023



Source: Hitachi Zosen Report (2019) and MEM

90% of domestic Laos market consumes electricity produced by hydropower dams (run off river type). There is a definite difference in electricity in the dry season and the rainy season. In rainy season, there is full capacity of electricity generation, which cause electricity surplus due to oversupply (Figure 4). The surplus electricity (blue line) was minimum in March at about 650 GWh/month and maximum in August at around 1,000 GWh/month. This amount based on number of power plants and domestic consumption in 2019.

Figure 5 shows the monthly domestic electricity generation, domestic electric power demand and the surplus electric power. The surplus electricity (red line) in 2023 is minimum in February at about 400 GWh/month and maximum in August at about 2,400 GWh/month. This amount can be utilized for export, but probably occurs in the rainy season only. As stated in the Hitachi Zosen

Report (2019), it is necessary to examine the status of the domestic grid at the time of occurrences and generation status at each area. However, there is no detailed data provided at this time. However, the new administration probably revises electricity demand forecast due to previous overestimate and current circumstance. It is necessary to continue request the Ministry of Energy and Mines and the EDL to provide relevant up-to-date data and perform detailed electricity peak supply and demand monthly.

1.2.3 Electricity Development Plan

Table 2 shows ongoing hydropower plants under construction and on the demand forecast to generate electricity. The capacity of these dams is totally 3,149 MW and expected to produce more than 13,000 GWh annually. According to the 9th 5-Year Energy and Mines Development Plan, it expects to generate 276,096 GWh of electricity in the five year (2021-2025), for export and domestic supply, which increases approximately 79% of the 8th 5-Year plan.

Note that the new administration probably revises electricity demand forecast due to previous overestimate and current circumstance as well.

Table 2: Ongoing-operated and under construction hydropower plants, >15 MW

	Hydropower	Capacity (MW)	Output (GWh/year)	Completion Year	Developer	Market
1	Nam Ou 1	180	710	2020	Sino Hydro (Chinese Public Company)	EDL [domestic market]
2	Nam Ou 3	210	826	2020		
3	Nam Ou 4	132	519	2020		
4	Nam Ou 7	210	838	2020		
5	Nam Ngum 3	480	2,345	2020[11]	Sino Hydro (Chinese Public Company) & EDL	EDL
6	Nam Tha Had Mouak	37.5		(by 2020)	Nam Tha-Had Mouak Hydropower Company	EDL [domestic market]
7	Nam Mo 2	120	459.77	(by 2020)	Lao private companies (Phongsapthavy Company & Duangchalern Company) and Vietnamese private companies (Nam Mo Electric Company & Dongteum Commercial Company)	EDL [domestic market]
8	Nam Ngum 4	240	872	2023[12]	EDL	N/A
9	Nam Lik 1	65	248.60	2019[13]	Foreign private companies (HEC, GPSC, & POSCO) & EDL	EDL [domestic market]

[11] https://www.adb.org/sites/default/files/project-document/74126/40906-014-lao-remdp.pdf
[12] https://reconnectingasia.csis.org/database/projects/nam-ngum-4-hydroelectric-power-project/f30343d4-a1cd-4b5a-9b3c-ad865edf1873/
[13] https://www.gpscgroup.com/en/business/project/167/nam-lik-1-power-company-limited-nl1pc

10	Nam Theun 1	650	2,561	2022[14]	Phonsak Group & EDL-GEN	80% export to Thailand and 20% EDL [domestic market]
11	Nam Hinboun	30	197	2020	EDL	EDL
12	Xelanong 1	70	286	(by 2025)	YEIG International Development Co., Ltd, Daosavanh Group & Sun Paper Holding	N/A
13	Xekaman 3	250	982.88	(by 2030)	N/A	N/A
14	Don Sahong	260	2028	2019-2020	Mega First (Malaysia) & GOL	EDL [domestic market]
15	Nam Kong 1	160	649	(by 2025)	CWE (Chinese Public Company), EDL & Investment Consultant and Dam Construction Company	N/A
16	Nam Kong 3	54	198	(by 2020)	Houang Anh Gnai Lai & EDL	EDL [domestic market]
	Total	3,148.5	13,720.25			

Source: A direct source from MEM Development Plan

Remarks: years in parentheses denote as planned completion date

[14] https://www.nt1pc.com/about-us/

1.2.3.1 Domestic consumption

Electricity consumption increased to 5,417 GWh in 2018, which is around 9% increase from the previous year. Its proportion of electricity consumption is that industrial sector accounted for 42%; residential sector accounted for 35%; commercial sector accounted for 22%; and the rest of electricity consumption went to agricultural sector. In 2019, electricity consumption increased to 6,596 GWh which is around 22% increase from the previous year. Based on five electricity demand assumptions: (i) economic growth, (ii) EV usage covers around 30% of total vehicles by 2030, (iii) industrial sector growth rate, (iv) EV usage increases and industrial sector growth rate, and (v) COVID-19 pandemic. Domestic demand in the next five years will rise by about 8.1%-10.7%. In 2025, the minimum demand will be 2,132 MW and the maximum demand will be 2,880 MW. During 2021-2025, domestic consumption will be 28,176 GWh (28,176 GWh is from IPP and 3,000 GWh is imported).

Table 3: Domestic Consumption by Sector (GWh)

Year	Residential	Commercial	Industrial	Others	Total
2011	1,004	765	584	46	2,399
2012	1,161	993	681	39	2,874
2013	1,278	949	1,118	35	3,381
2014	1,424	767	1,564	36	3,791
2015	1,595	867	1,745	33	4,239
2016	1,735	974	1,916	34	4,660
2017	1,814	1,038	2,087	27	4,966
2018	1,913	1,188	2,286	29	5,417

2019	2,136	1,319	3,099	42	6,596

Source: EDL

1.2.3.2 Export

In the next five years, Laos expects to export electricity to Thailand, Vietnam, Cambodia, Singapore, Malaysia, and Myanmar as shown in Table 4.

Table 4: Electricity export plan (2021-2025)

Country	Electricity Export Base on MOU
Thailand	Laos expects to export 9,000 MW - Currently exporting 5,861 MW - Plan to export another 1,020 MW
Vietnam	Laos expects to export 3,000 MW - Currently exporting 572 MW - Plan to export another 468 MW - Additional export 1,500 MW
Cambodia	Laos expects to export 3,095 MW - Currently exporting 195 MW - Plan to export another 1,700 MW
Malaysia	Laos expects to export 300 MW in 2020-2022
Singapore	Laos expects to export 100 MW in 2022-2024
Myanmar	Laos expects to export 35 MW

Source: A direct source from MEM Development Plan

1.2.4 Electricity Tariff

Table 5 shows an average domestic tariff of electricity from 2008 to 2019. It varies between 6 to 9 USD cent per 1 kWh. According to the *MEM's Announcement on Domestic Tariff of Electricity Revision in 2021, No. 0396/cabinet, issued date on 4 March 2021*[15], domestic tariff increased approximately 2% of 2017-2019 rate covering all sectors.

[15] The Announcement on Domestic Tariff of Electricity Revision in 2021, No. 0396/cabinet, issued date on 4 March 2021. [Lao language]

On the other hand, statistics of average electricity tariff of export shown in Table 6. An average tariff rate refers to information reported by the EDL that includes only Nam Ngum 1, Nam Leuk, Nam Mang 3, and Xeset grids 1 & 2.

Table 5: Statistics of average electricity domestic Tariff

Year	Average in Kips/KWh	Equivalent USD cent/KWh	Average Exchange Rate
2008	542	6.22	8,720
2009	547	6.41	8,533
2010	559	6.77	8,262
2011	559	6.95	8,047
2012	622	7.75	8,023
2013	666	8.48	7,857
2014	691	8.56	8,065
2015	709	8.69	8,153
2016	717	8.80	8,146
2017	721	8.75	8,270
2018	724	8.59	8,433
2019	696	7.99	8,715

Source: A direct source from EDL

Table 6: Statistics of average electricity tariff of export

	EGAT (Thailand)		Cambodia		Average [a]	
Year	Kip/kWh	USD Cent/kWh	Kip/kWh	USD Cent/kWh	USD Cent/kWh	Average Exchange Rate
2006	-	-	-	-	-	10,147
2007	355	3.69	-	-	-	9,603
2008	315	3.61	-	-	-	8,720
2009	310	3.64	-	-	-	8,533
2010	324	3.92	580	7.02	-	8,262
2011	312	3.87	565	7.02	-	8,047
2012	304	3.79	698	8.70	-	8,023
2013	299	3.81	684	8.70	-	7,857
2014	304	3.77	727	9.01	3.93	8,065

2015	302	3.71	756	9.27	3.73	8,153
2016	-	-	-	-	3.76	8,146
2017	-	-	-	-	3.92	8,270
2018	-	-	-	-	3.93	8,433
2019	-	-	-	-	5.17[b]	8,715

Source: A direct source from EDL

Remarks: [a] Nam Ngum 1, Nam Leuk, Nam Mang 3, and Xeset grids 1 & 2

[b] included tariff rate for Cambodia, Myanmar, and Malaysia buyers

1.2.5 Biomass Production

For biomass, the production is mainly from fuelwood and charcoal as shown in Table 7. There are few biomass productions from bagasse. Based on ERIA's report, the biomass power production is based on the international efficiency standard for biomass power production.

For fuelwood, ERIA (2018) stated that fuelwood production data is lower than consumption data. This trend is similar to charcoal until 2010. After 2010, charcoal production increased rapidly. The data on charcoal production was revised by assuming that production equals consumption.

Table 7: Biomass production and consumption (kt)

Year	Charcoal			Fuelwood (kt)					Bagasse	
	Production	Consumption		Production	Consumption				Production	Consumption
		Commercial	Residential		Commercial	Residential	Industry	Industry Charcoal		
2000	102	53	50	3,298	420	2,346	123	410	-	-
2001	105	54	51	3,377	430	2,402	126	419	-	-
2002	107	55	52	3,458	440	2,459	129	429	-	-
2003	110	56	53	3,540	451	2,518	133	439	-	-
2004	112	58	55	3,625	461	2,579	136	449	-	-
2005	115	59	56	3,712	473	2,641	139	459	-	-
2006	117	60	57	3,800	484	2,704	142	470	-	-
2007	130	67	64	4,120	523	2,922	154	522	-	-
2008	154	79	75	4,476	561	3,135	165	616	-	-
2009	183	94	89	4,462	542	3,028	159	732	-	-
2010	186	95	91	4,371	527	2,946	155	743	-	-
2011	189	97	92	4,281	512	2,864	151	754	-	-
2012	191	98	93	4,149	498	2,781	104	765	-	-
2013	193	103	90	4,131	502	2,699	156	774	5	8
2014	199	108	91	4,181	508	2,727	149	797	5	8
2015	205	113	92	4,234	514	2,754	146	820	4	5

Source: An indirect source from ERIA (2018)

1.3 Potential Hydrogen Production

There is no data on potential hydrogen production in Laos. According to DPC's report number 460 [16] on energy and mines sector development plan (2021-2025), however, the government aspires to diversify electricity generation source for domestic consumption such as 65% of hydropower, 30% of coal-fired, and 5% of solar, wind and biomass power. They also promote clean energy utilization in transportation. 14% of vehicles in 2017, which is approximately 277,190 of vehicles, should be replaced by EVs or biofuel/biogas vehicles. Its initial stage starts from public transportation, and government's vehicles. Biofuel, and biogas (CH4) will be promoted for fuel import substitution. In addition, the government enhances to construct at least 100 EV and biofuel/biogas stations nationwide. Energy saving campaign will be promoted in public sector (e.g. government buildings, vehicles, etc.), industrial sector (e.g. Vangvieng Cement Factory, Tobacco Factory), and business sector (e.g. Vientiane Plaza Hotel, Lao-ITECC).

1.4 Potential cement production

Currently, there are 16 cement plants in operation or under construction have a total production capacity of 6.76 million tons per year [17]. The government has approved the establishment of 18 cement factories around the country with capacity of 12 million tons a year.[18] The 9th 5-year plan does not set any target of achievement to exploit limestone.

[16] DPC (2021). Report No. 460/MEM.DPC, 22 April 2021. [Lao language]
[17] Global Cement (2018), https://www.globalcement.com/news/itemlist/tag/Vientiane%20Hongshi%20Xaythirath
[18] The Nation Thailand (2021), https://www.nationthailand.com/aec/30299699

Table 8: Operating cement factories

No.	Company Name	Investment	Area (ha)	Province	Operation Date	Period (Year)
1	VSK Lock Crushing Ltd., Co.	Foreign	15	Khammouan	1995	20
2	Lao Cement Public Company	Joint-venture	53.5	Vientiane	1998	27.5
3	Zhongyayici Lao Cement Ltd., Co.	Foreign	500	Salavan	2002	32.6
4	Sila Khammouan Limited Partnership	Joint-venture	50	Khammouan	2006	30
5	Lao Cement Industry Ltd., Co.	Joint-venture	1,838	Khammouan	2006	33
6	Agriculture-Industry Development and Export-Import State Enterprise	Lao	18	Vientiane	N/A	N/A
7	Pha Nangnone Mining Ltd., Co.	Lao	30	Khammouan	2007	30
8	Vang Vieng Lao Cement Ltd., Co. (Builing No.3)	Joint-venture	71	Vientiane	2008	32
9	Hongsa Power Ltd., Co.	Joint-venture	1,050	Xayabouly	2009	25
10	Unichamp Lao Ltd., Co.	Joint-venture	50	Khammouan	2010	22
11	Oudomxay Cement Ltd., Co.	Lao	240	Oudomxay	2012	24
12	Krisana Silaphet Ltd., Co.	Lao	4	Khammouan	2012	20
13	Lao Cement Industry Development Sole Ltd., Co.	Lao	368	Khammouan	2014	24.6
14	Khammouan Cement Ltd., Co.	Joint-venture	3,440	Khammouan	2014	30
15	Lanexang Cement Lao Ltd., Co.	Joint-venture	572	Khammouan	2014	24
16	Vientiane Hongshi Saythirath Cement Ltd., Co.	Foreign	404	Vientiane	2016	23

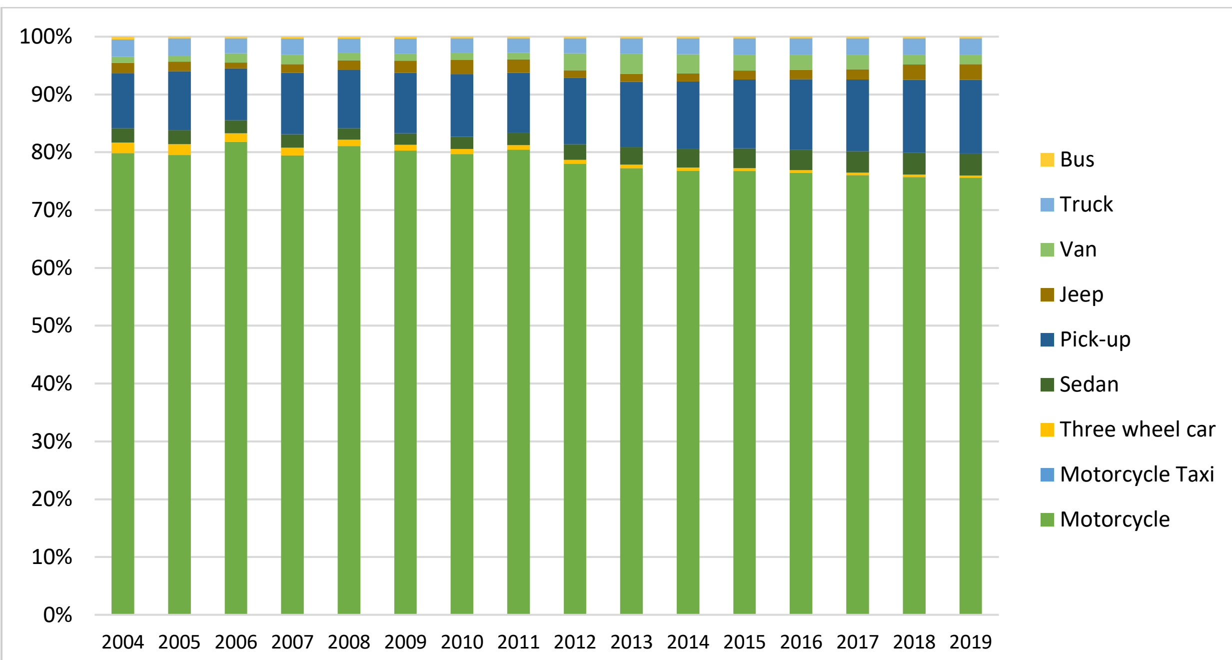
Source: A direct source from MEM (The 9th 5-year plan 2021-2025)

1.5 Transport Sector

1.5.1 Number of Vehicles

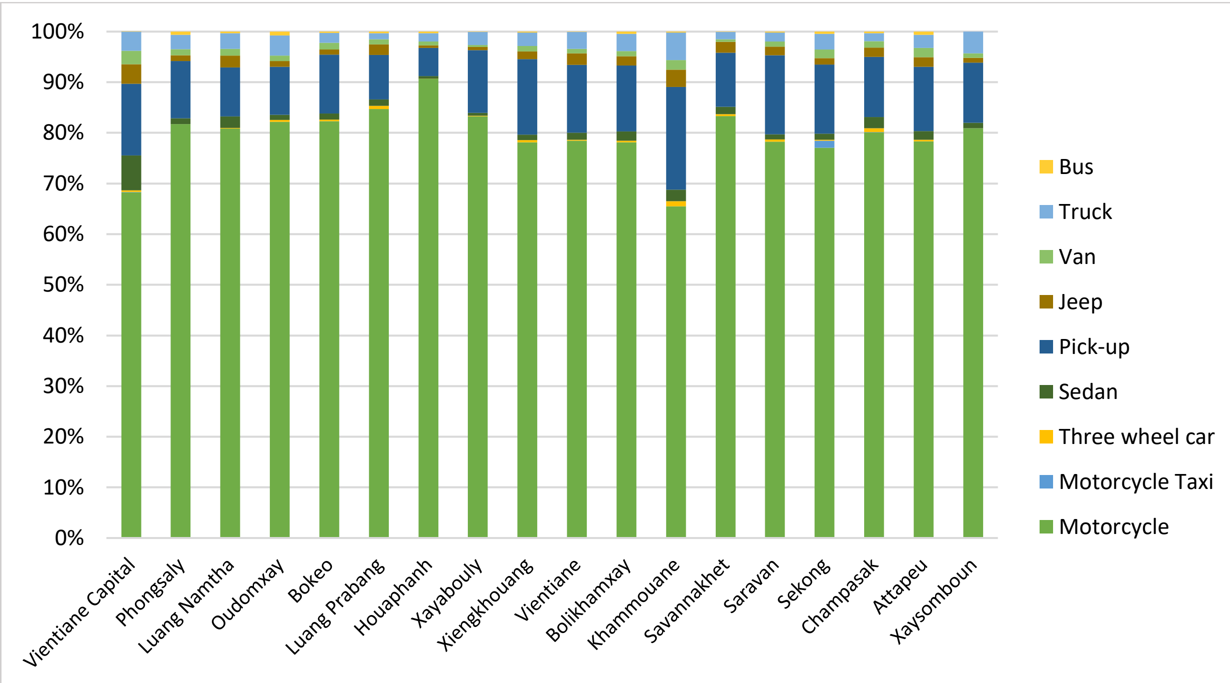
The total number of vehicles is the activity data for the road transport sector. The data was based on annual vehicle registrations. DOT provided a proportion of vehicle by type from 2004-2019 (Figure 6) and a proportion of vehicle by type and province in 2019 (Figure 7). Based on ERIA report, total number of vehicles in Laos increased by 13% per year, from around 80,000 in 1990 to almost 1.8 million in 2016. This number increased to 2.2 million in 2019.

Figure 6: A proportion of vehicle in Lao PDR, 2004 - 2019



Source: A direct source from DOT, PWT

Figure 7: A proportion of vehicle by province, 2019



Source: A direct source from DOT, PWT

The majority type of vehicles were motorcycles. Its shares decreased from 80% in 2011 to 75% in 2019. Meanwhile shares of other types of vehicles increased such as sedan, pick-up, jeep, and truck.

1.5.2 Fuel Economy by Vehicle Types

There is no official data concerning light oil and LPG/CNG[19] usage by vehicle types. It is similar to data on average age of all vehicles. Due to this limitation, we then obtained data from ERIA survey in 2018. A parking lot survey was conducted in several locations in Vientiane (Anou

[19] Since methane produced via the P2G technology is interchangeable with CNG as fuel for motorized vehicles, the current and future projections of CNG vehicle usage is explored in this report, specifically with the aim of assessing the possibility of green methane replacing CNG. Since methane and natural gas are almost identical, the term "CNG vehicles" is used in this report as this type of vehicle is commonly referred to as such even when it runs on methane gas.

Park, Aussie market, ITTEC Shopping Mall, Khet Market, Kuadin Market, Nong Niew Market, Sikhay Market, Victory Monument, View Mall, and VTE Center). The sample was 200 vehicles. Pick-up cars accounted for 37% of the sample, it followed by motorcycles (20%), sedans (12%), vans (10%), trucks (10%), three wheels (6%), and SUV (5%). Table 8 shows the average fuel economy and distance travelled for gasoline and diesel vehicles by type based on ERIA's calculation.

Table 9: Fuel economy and distance, 2018

Vehicle type	Average KM/liter		Average KM/year	
2018	Gasoline	Diesel	Gasoline	Diesel
Motocycle	20.50	-	5,104	-
Motortricycle	10.00	-	15,974	-
Sedan	9.60	9.50	15,236	16,276
Pick-up	-	9.10	-	16,712
Mini Bus	-	9.20	-	18,206
Jeep (SUV)	9.90	9.30	16,006	16,995
Truck	9.80	9.80	31,633	14,080
Bus	-	3.40	-	4,990

Source: ERIA (2018)

1.5.3 Fuel and Gas

DEPP collects fuel consumption data from the Lao State Fuel Company. Data is available for 2000-2015 only as shown in Table 10. Fuel consumption in transport sector consists of four types of fuel such as JET A-1, gasoline, Diesel, and lubricant. LPG consumption data is broken down into commercial and residential sectors. For residential sector, there is no official record for LPG price. However, based on a price for regular household consumption in Vientiane Capital, LPG price for 15 kg is approximately 135,000 kip or 14.4 USD.[20] The price might be different in other districts and provinces.

Note that there is no public disclosed data on LPG/CNG price.

Table 10: Consumption of petroleum products in transport (Kilolitre)

	Transport				Commercial	Residential
Year	Jet A-1	Gasoline	Diesel	Lubricant	LPG	
2000	54,420	100,746	201,569	-	970	-
2001	68,009	100,439	236,513	-	970	-
2002	69,154	107,002	238,059	-	979	-
2003	78,622	110,200	250,615	-	981	-
2004	81,992	117,879	257,323	-	1,001	-
2005	88,909	124,301	266,825	-	1,001	-
2006	89,908	134,654	282,850	-	1,122	-
2007	97,723	161,672	307,177	-	1,130	-
2008	67,564	165,401	365,013	-	1,136	-
2009	18,359	155,118	430,015	-	1,389	-
2010	13,359	152,885	436,034	-	1,431	-
2011	17,721	144,804	439,805	-	1,506	-
2012	29,256	139,559	510,293	1,840	1,560	-
2013	37,968	215,650	533,735	1,852	1,642	-
2014	42,603	210,416	654,122	1,919	-	-
2015	46,262	223,318	863,281	3,904	-	-

Source: ERIA' compilation from DOC, MOF

1.6 Future Energy Demand

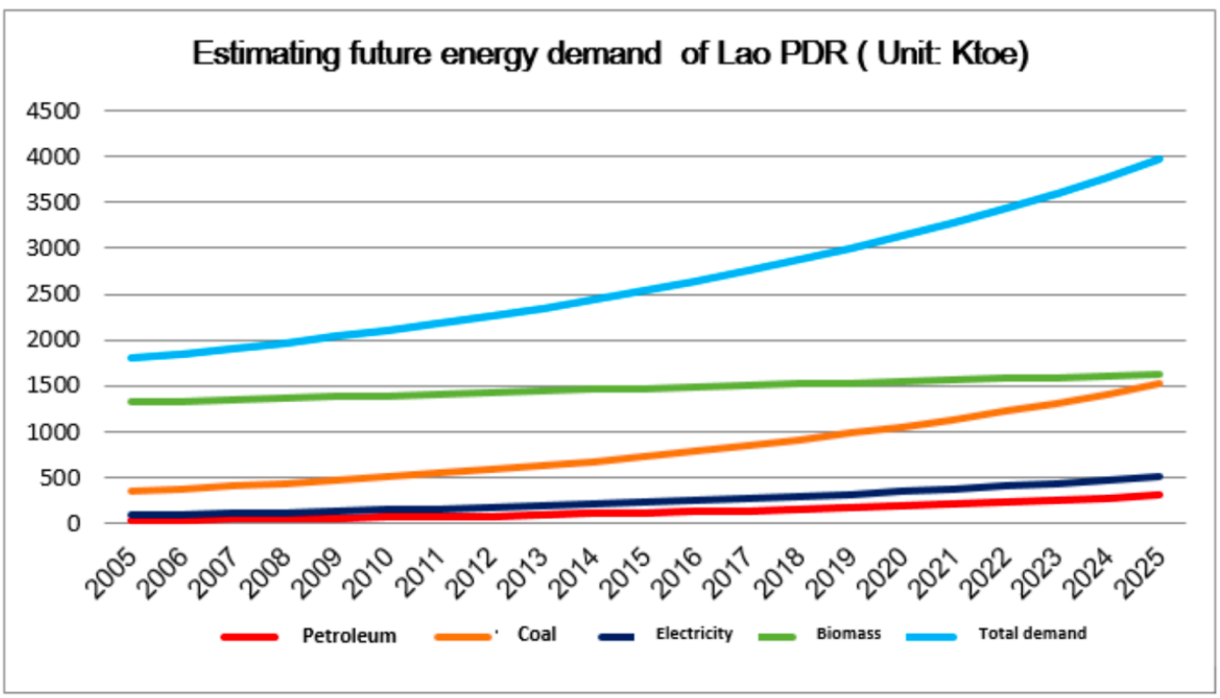
According to *the first biennial update report (BUR)*[21] by the MONRE in 2020, an energy demand for the whole country was estimated to increase about 3.6% per year. It was from 1.8 million tons in 2005 to 3.9 million tons in 2025, which showed different amount from different sectors. Household sector's demand was expected to decrease from 77.8% in 2005 to 48.5% in

[20] BOL exchange rate 9,140 Kip = 1 USD as of 8 April 2021
[21] MONRE (2020). The First Biennial Update Report (BUR), as of July 2020, by the MONRE, Lao PDR.

2025. Industry sector's demand, on the other hand, probably increased from 6.1% in 2005 to 16.9% in 2025 (Figure 8).

According to Ministry of Energy and Mining's report in November 2021, it revealed electricity demand under the BAU will increase from 1,380 MW (8,564 GWh) in 2021 to 1,902 MW and 2,541 MW in 2025 and 2030, respectively. On average, it will increase around 7% annually. If the government promotes EV to be used widely and industries demands also rise, electricity demand will increase around 7.9% annually. In contrast, the COVID-19 pandemic will decrease electricity demand around 6.1%.

Figure 8: Estimated Future Energy Demand in Lao PDR (Ktoe)



Source: MONRE (2020), MEM (2018), and ERIA (2018).

As the P2G project relies on CO2 free from industries' emissions and surplus electricity available in Laos, however, there are two issues could affect electricity consumption and generation in the future. First is the Laos-China railway and cryptocurrency mining. The power supply project for the China-Laos Railway is the first BOT (build-operate-transfer) power grid project in Laos, a key project to guarantee the operation of the China-Laos Railway. The construction of the project was kicked off at the end of 2019 and concluded in March 2021. It includes building 20 circuits of 115kV transmission lines with a total length of 257 km and extends 11 bays in 10 substations in order to supply power from the state-run EDL's grid to 10 railway traction substations. The project includes 2,220 transmission poles with a total length of 936 kilometers with links to 24 traction substations. Laos-China Power Investment Company, co-sponsored by China Southern Power Grid (CSG) and the EDL, was established in November 2019 in Vientiane. The China Southern Power Grid Company saying the railway will be a green, low-carbon electrified railway. The energy demand projection may increase and need more power supply, depending on the actual business run of the railway operation.

Moreover, on 9th November 2021, Ministry of Technology and Communications promulgated Decree on the Pilot Implementation of Digital Currency Transaction[i]. It allows two digital currency businesses to be implemented in Laos, such as cryptocurrency mining and buying/selling cryptocurrency. Permitted companies to operate crypto mining signed MOUs to buy nearly 300 MW of electricity in the first three years and expected to buy more around 100 MW in a rainy season. Second, there will be a potential energy generation from alternative sources to top up existing electricity generation capacity. It includes a 1,200 MW of floating solar farms on Nam Ngum 1 dam reservoir by the China-based company (PDA signed), a 240-250 MW floating solar power plant at Nam Theun 2 dam by the French energy giant EDF, and a 600 MW wind farm by the Mitsubishi and Thai company in the southern province. Moreover, the Lao government aspires to increase renewable energy sources for electricity generation to 30% by 2030, which a currently proportion is 2%.

Regarding JICA's assessment on electric power to Green Hydrogen[ii] points out that, in 2020, energy surplus in Laos during a rainy season was around 498 GWh and energy deficit was around 23 GWh in some area. On the other hand, in a dry season, energy deficit was nearly 220 GWh and energy surplus occurred in the south 21 GWh. For these reasons, it is essential to adjust energy generation and utilize energy surplus to produce hydrogen that need carefully study in order to maximize Laos' electricity generation potential.

1.7 Greenhouse Gas Emissions

The latest official data of GHG inventory in Laos is 2014 due to the BUR by MONRE. The net emission was 4,100 $GgCO_{2eq}$ (Table 11). AFOLU was the largest sources of emissions, which accounted around 78%. It followed by energy sector (15%), industrial processes and product use (5%) and, wasted (2%). The energy sector's emission consists of fuel combustion and fugitive emissions from fuel. The CO_2 in transportation and storage was included elsewhere or not estimated since data was inadequate. For industry sector, there were two industries that relevant to the GHG emissions in Laos: mineral industry (cement and line, and metal rod production) and industrial products that potentially emit HFCs, PFCs and SF6 (but its quantity of industrial products was relatively).

Table 11: Total GHG Emissions in 2014

Categories	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)					Emissions (Gg)
	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2	CO2e
Total National Emissions and Removals	**15,441.035**	**300.562**	**7.571**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**24,099.98**
1 - Energy	**3,343.418**	**5.958**	**0.842**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3,729.42**
1.A - Fuel Combustion Activities	3,343.418	5.843	0.842	0	0	0	0	0	0	0	0	0	3,727.00
1.A.1 - Energy Industries	0	5.381	0.718						0	0	0	0	335.44
1.A.2 - Manufacturing Industries and Construction	27.042	0.001	0.000						0	0	0	0	27.16
1.A.3 - Transport	2,281.649	0.270	0.113						0	0	0	0	2,322.40
1.A.4 - Other Sectors	1,034.726	0.190	0.011						0	0	0	0	1,042.01
1.B - Fugitive emissions from fuels	0	0.115	0	0	0	0	0	0	0	0	0	0	2.41
1.B.1 - Solid Fuels	0	0.115	0						0	0	0	0	2.41
2 - Industrial Processes and Product Use	**1,151.890**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,151.89**
2.A - Mineral Industry	1,090.245	0	0	0	0	0	0	0	0	0	0	0	1,090.24
2.A.1 - Cement production	1,087.294								0	0	0	0	1,087.29
2.A.2 - Lime production	2.951								0	0	0	0	2.95
2.B - Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0	-
2.C - Metal Industry	61.646	0	0	0	0	0	0	0	0	0	0	0	61.65
2.C.1 - Iron and Steel Production	61.646	0							0	0	0	0	61.65
2.D - Non-Energy Products from Fuels and Solvent Use	0	0	0	0	0	0	0	0	0	0	0	0	-
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0	-
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0	0	0	0	0	0	0	0	0	-
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0	-
3 - Agriculture, Forestry, and Other Land Use	**10,943.431**	**280.544**	**6.318**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**18,793.41**
3.A - Livestock	0	179.826	0.615	0	0	0	0	0	0	0	0	0	3,966.89
3.A.1 - Enteric Fermentation		152.914							0	0	0	0	3,211.19
3.A.2 - Manure Management		26.912	0.615						0	0	0	0	755.69
3.B - Land	9,093.245	0	0	0	0	0	0	0	0	0	0	0	9,093.25
3.B.1 - Forest land	(12,661.984)								0	0	0	0	- 12,661.98
3.B.2 - Cropland	19,314.621								0	0	0	0	19,314.62
3.B.3 - Grassland	8.148								0	0	0	0	8.15
3.B.4 - Wetlands	0		0						0	0	0	0	-
3.B.5 - Settlements	91.672								0	0	0	0	91.67
3.B.6 - Other Land	2,340.789								0	0	0	0	2,340.79
3.C - Aggregate sources and non-CO2 emissions sources on land	25.883	100.718	5.703	0	0	0	0	0	0	0	0	0	3,908.98
3.C.1 - Emissions from biomass burning		46.057	0						0	0	0	0	967.19
3.C.2 - Liming	1.731								0	0	0	0	1.73
3.C.3 - Urea application	24.152								0	0	0	0	24.15
3.C.4 - Direct N2O Emissions from managed soils			4.215						0	0	0	0	1,306.59
3.C.5 - Indirect N2O Emissions from managed soils			1.355						0	0	0	0	420.05
3.C.6 - Indirect N2O Emissions from manure management			0.133						0	0	0	0	41.37
3.C.7 - Rice cultivations		54.662							0	0	0	0	1,147.90
3.C.8 - Other (please specify)		0	0						0	0	0	0	-
3.D - Other	1,824.303	0	0	0	0	0	0	0	0	0	0	0	1,824.30
3.D.1 - Harvested Wood Products	1,824.303								0	0	0	0	1,824.30
3.D.2 - Other (please specify)	0	0	0						0	0	0	0	-
4 - Waste	**2.296**	**14.060**	**0.412**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**425.26**
4.A - Solid Waste Disposal	0	2.624	0	0	0	0	0	0	0	0	0	0	55.10
4.B - Biological Treatment of Solid Waste	0	0.005	0	0	0	0	0	0	0	0	0	0	0.10
4.C - Incineration and Open Burning of Waste	2.296	0	0	0	0	0	0	0	0	0	0	0	2.30
4.D - Wastewater Treatment and Discharge	0	11.431	0.412	0	0	0	0	0	0	0	0	0	367.76
4.E - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0	-
5 - Other	0	0	0	0	0	0	0	0	0	0	0	0	-
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	0	0	0	0	0	0	0	0	0	0	0	0	-
5.B - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0	-
Memo Items (5)													-
International Bunkers	53.068	0.000	0.001	0	0	0	0	0	0	0	0	0	53.54
1.A.3.a.i - International Aviation (International Bunkers)	53.068	0.000	0.001						0	0	0	0	53.54
1.A.5.c - Multilateral Operations	0	0	0	0	0	0	0	0	0	0	0	0	-

Source: Lao PDR MONRE (2020). Obtained for this project.

Figure 9 shows an overview of GHG emissions from the base year 2000 according to the 3 scenarios as follows:

1) A baseline scenario is a reference case that illustrates future GHG emission levels, which most likely to occur in the absence of GHG mitigation activities.

2) An unconditional mitigation scenario reflects GHG emissions reduction efforts that Laos commit to and based on own resources and existing levels of supports from parties.

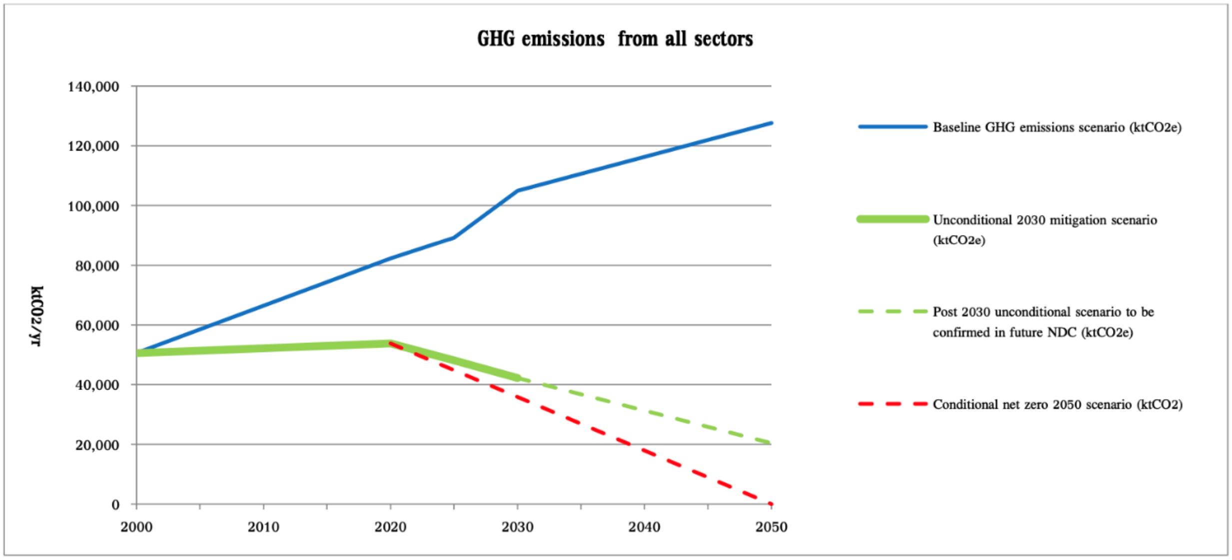
3) A conditional mitigation scenario represents additional GHG emissions reduction efforts that Laos can achieve and based on own resources and existing levels of supports from parties.

In 2000, the total emissions of GHG in Laos was 50,742 KtCO2e.[22] The Land Use Change & Forestry (LUCF) and Agriculture accounted for more than 95%. Emissions from economic and population growth increased by 7.2% and 1.6% per year respectively between 2000 and 2018.

Under the baseline scenario, the total GHG emissions levels in Laos is expected to reach 82,000 ktCO2e in 2020 and 104,000 ktCO2e in 2030. Major contributors are LUCF, agriculture, transportation, and energy sector (coal-fired power plants).

[22] MONRE (2021). Nationally Determined Contribution (NDC). March 2021.

Figure 9: GHG Emissions Scenario from All Sectors



Source: Lao PDR MONRE (2021)

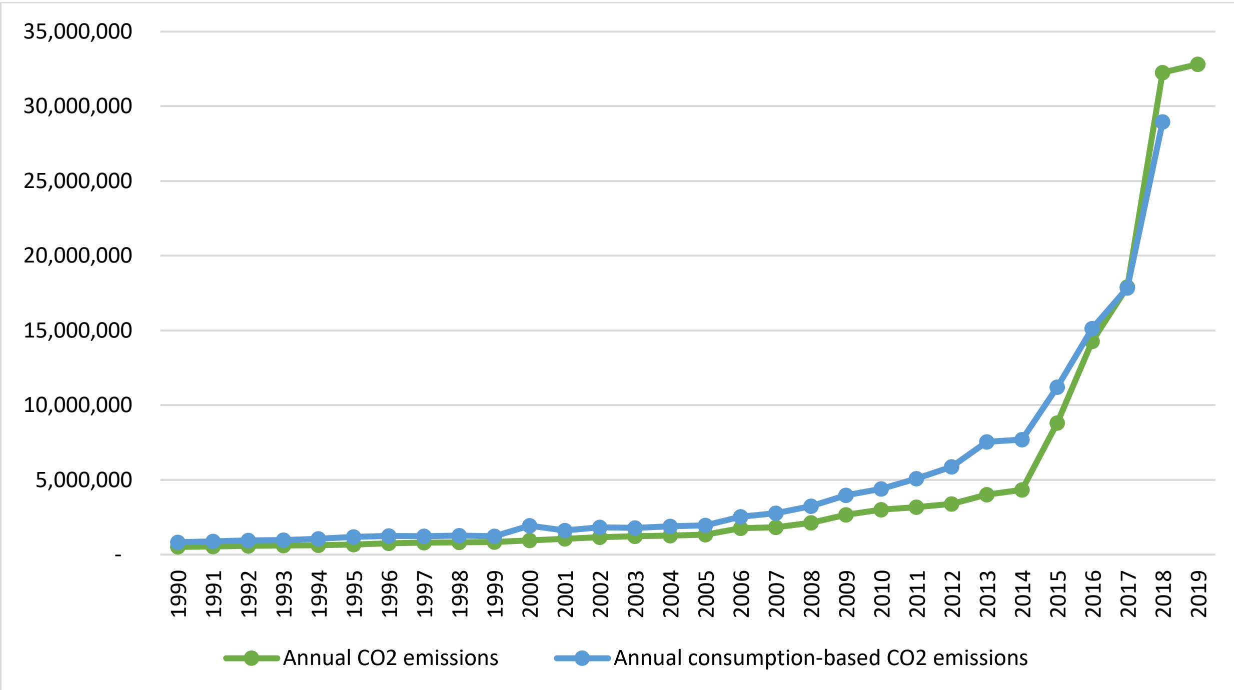
Remarks: Value in 2020 on green line (unconditional 2030 mitigation scenario ~) is an estimated current level of emissions.
The dash green line represents a communicated in the future NDC submissions.

1.8 Additional GHG Emissions Information

1.8.1 Carbon Dioxide Emissions

Figure 10 displays annual production-based and consumption-based emissions. According to the Global Carbon Project, CO_2 emissions tend to be focused on production-based within a country's own borders. An annual production-based CO2 emissions are measured from the burning of fossil fuels for energy and cement production. Land use change is not included. The Global Carbon Project estimate an annual consumption-based emissions by correcting for trade. If a country imports goods the CO_2 emissions needed to produce such goods are added to its domestic emissions; if it exports goods then this is subtracted.

Figure 10: Annual Production-Based vs. Consumption-Based CO_2 Emissions (tons)



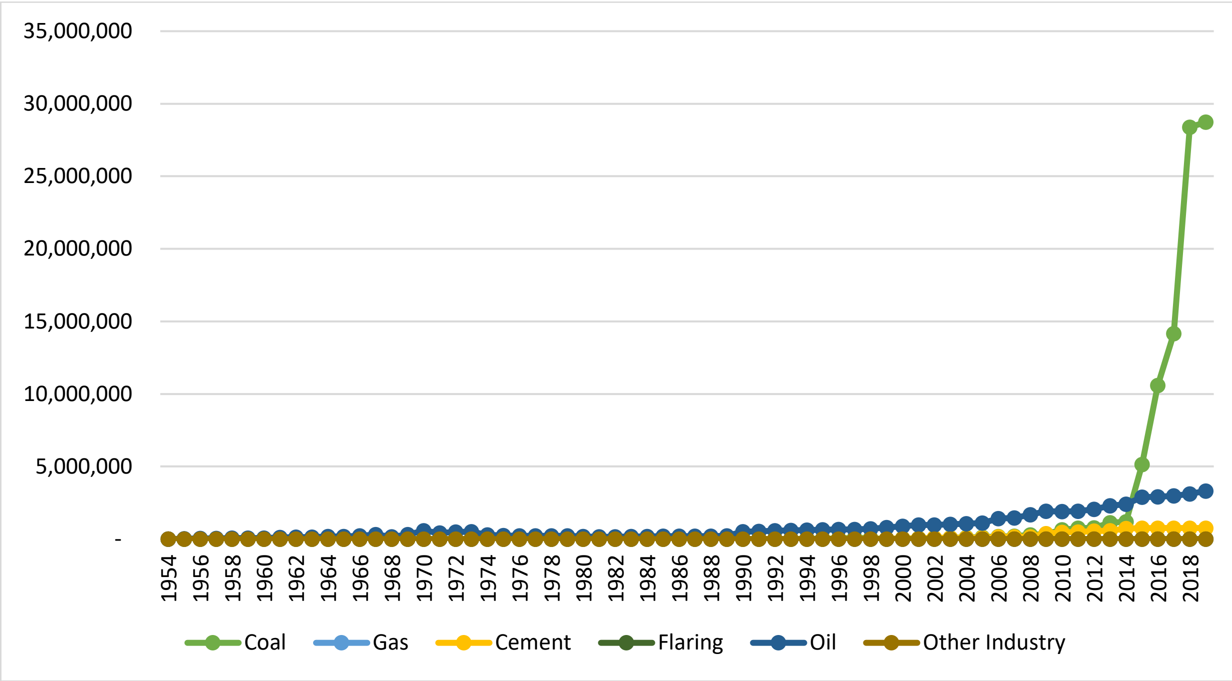
Source: (Updated) Peters et al. (2011). Global Carbon Project.[23]
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/
Remarks: This measures CO2 emissions from fossil fuels and cement production only - land use change is not included.

1.8.2 Industrial Sector

Figure 11 shows CO_2 emissions that dominated by the burning of fossil fuels for energy production, and industrial of materials such as cement. It shows the breakdown of annual CO2 emissions by source: either coal, oil, gas, cement production or gas flaring. This breakdown is strongly influenced by the energy mix of Laos, and changes as a country shifts to or from a given energy source. Coal is the dominating in CO2 emitted, which followed by oil, and cement sources.

[23] Hannah Ritchie and Max Roser (2020) - "CO_2 and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions' [Online Resource]

Figure 11: CO_2 Emissions by Source (tons)



Source: (Updated) Peters et al. (2011). Global Carbon Project. [22]

1.8.3 Transport Sector

Similarly with other types of data, there is a limitation of official data concerning greenhouse gas emissions. For this reason, we obtained CO_2 emissions data from JICA's final report on the *Basic Data Collection Study on Low-emission Public Transport System in Lao PDR.*[24]

CO_2 emissions was calculated based on fuel types and emissions factors by vehicle types. In the absence of relevant emissions coefficients in Laos, the data for Thailand was adopted due to similarity in vehicle types. The vehicle kilometrage was adjusted from an observed data in Laos.

[24] JICA (2016). Basic Data Collection Study on Low-emission Public Transport System in Lao PDR.

The estimated volumes of CO_2 emissions from vehicles shown in Table 12.

Table 12: CO_2 emissions from vehicles, 2016

	Amount if CO_2 (thousand tons)			Increase/Year (%)		Assumptions	
	2010	2020	2030	2011-2020	2020-2030	Emission Factors (g/km)	Driving Distance (km/year)
Motorcycle	190	298	363	4.60	2.00	44	5,840
Motor-tricycle	13	122	159	25.20	2.70	92	16,425
Sedan	42	134	275	12.50	7.40	231	9,125
Pick-up	310	858	1,527	10.70	5.90	306	9,125
Jeep (SUV)	310	858	1,527	10.70	5.90	306	9,125
Truck	627	991	1,460	4.70	4.00	739	36,500
Bus	119	206	333	5.60	4.90	1,056	43,800
Mini Bus	13	122	159	25.20	2.70	317	43,800
Medium bus	126	536	1,139	15.60	7.80	528	43,800
Song Thaew	126	536	1,139	15.60	7.80	306	18,250
Total	1,426	3,146	5,255	8.20	5.3		

Source: An indirect source from JICA – Final Report: Basic Data Collection Study on Low-emission Public Transport System in Lao PDR

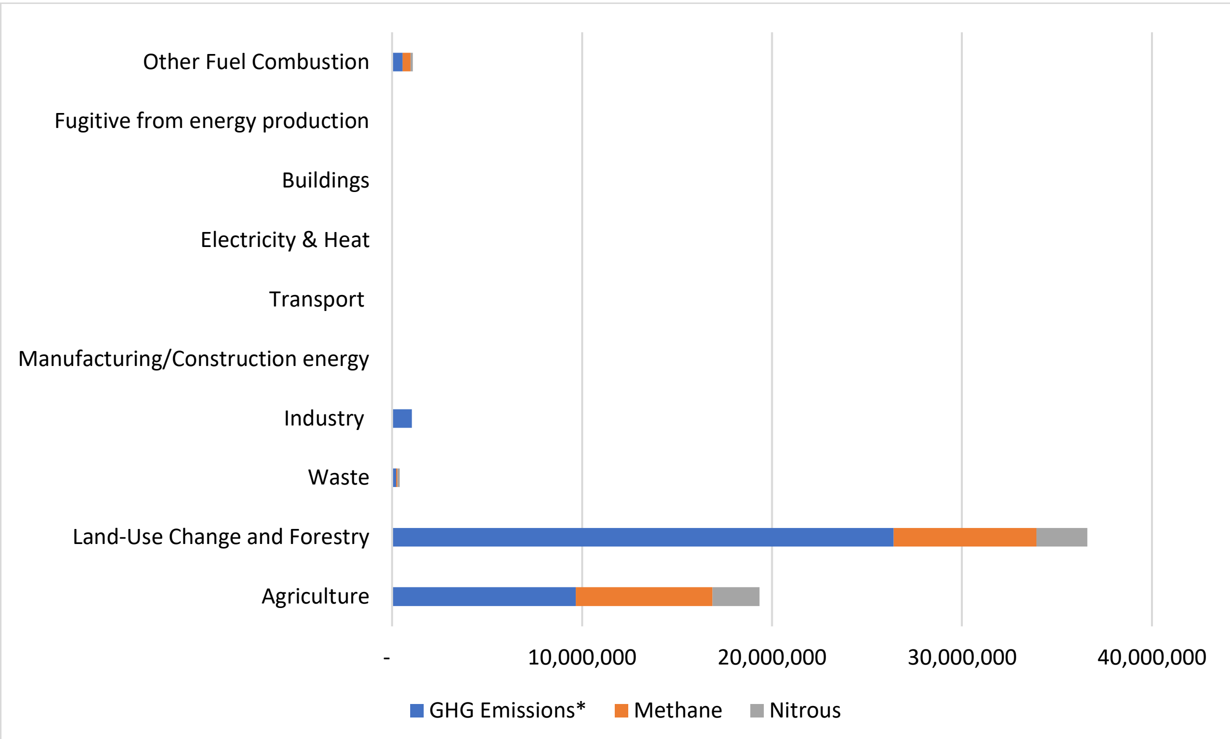
1.9 GHG by Sector

GHG emissions are summed up of carbon dioxide, methane, nitrous oxide, and F-gases. According to the CAIT Climate Data Explorer, GHG emissions are measured in tons of carbon-dioxide equivalents (CO_2e), where the equivalent means having the same warming effect as CO_2 over a period of 100 years. Besides emissions from land use change are taken into account.

Methane (CH_4) is a strong GHG, mainly produced through agricultural activities such as rice production and livestock. It is leakages from oil and gas production.

Nitrous oxide (N_2O) is mainly produced from the use of synthetic and organic fertilizers to grow crop.

Figure 12: GHG Emissions by Sector, 2016 (tons)



Source: CAIT Climate Data Explorer via. Climate Watch. [xxiv]
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/
Remark:* Total GHG emissions – from CO_2, methane (CH_4), nitrous oxide (N_2O), and F-gases. GHG, Methane, and Nitrous emissions are measured in tons of carbon dioxide-equivalents (CO_2e)

1.10 Barriers and Suggested Initiatives

Since the P2G technology is not currently present in Lao PDR, there is a general lack of technical understanding about the technology itself, as well as the benefits that it could bring to the country. In addition, since Lao PDR relies mostly on imported fuels including gasoline, diesel and natural gas, the country does not have any legal or regulatory framework to safely produce and handle high pressure gas such as hydrogen and synthesis natural gas. These two areas of knowledge and capacity, when addressed in tandem, could potentially pave way for Lao PDR to create an environment where private sector see as a good investing opportunity.

In order to address the first area of knowledge there could be training, workshops, site visits and other educational opportunities particularly for the government personnel who are in the position to make decisions about the country's development and investment plans, policies, and strategies, as well as plans for international assistance requests such as official development assistance (ODA) to learn how they can potentially utilize the P2G technology to utilize surplus electricity instead of discarding it. Hydrogen or methane produced with the P2G technology and methanation process can be either exported to other countries, which will result in an increased income for the country, or it can be potentially used as fuel to generate electricity when the demand surpasses supply such as during the dry seasons, which will enhance their energy security. The latter may be particularly crucial in the face of the oncoming or worsening impacts of climate change as a country that almost entirely relies on hydropower for its electricity needs. This area of knowledge development is especially imperative in the early stage of capacity-building efforts since it will lay down a foundation for the relevant stakeholders to envision long-term goals and possible outcomes, which will inform their policymaking. Without the commitment and conviction of the decision-makers, P2G technology will have a diminished chance of receiving a spotlight in Lao PDR.

As for the second area of capacity, which is about laying out legal and regulatory framework necessary to safely produce and handle green hydrogen and possibly methane, will require legal experts to investigate corresponding laws and regulations in other countries that are already conducting pilot and commercial level P2G projects to see how they can replicate such laws in Lao PDR. This also extends to necessary regulatory framework that will allow the use of hydrogen and/or methane in the industrial sector and transport sector as fuels. This includes consideration and establishment of necessary legal and regulatory framework that lay out clear sets of rules and criteria for a wide array of aspects surrounding establishment and operation of P2G technology, such as high-pressure gas producer certification and permits granting processes; storage facilities and/or vessels, as well as other storage and distribution infrastructure, including FCEV charging stations; accidents prevention measures; routine inspections; waste disposal; and penalties for rule violations, among others. Possible capacity-building activities for this area include workshops and training for relevant personnel who are in charge of creating such laws and regulations within the country, as well as experts and researchers who may be able to provide expertise and guidance as necessary. To undertake effective knowledge and capacity-building, the first step would be to create a map addressing all necessary steps that the stakeholders in Lao PDR will need to take in order to introduce the P2G technology to the country, so that all efforts are well coordinated to maximize its impact and avoid duplication or oversight. Such steps and potential activities are discussed in the masterplan and the action plan, which are also part of this technical assistance project.

INDUSTRY SECTOR ANALYSIS

1.11 Status of Industries in Lao PDR – Hydro-Power Stations -

In our investigation, no significant industrial activities or factories were found in Lao PDR except for cement production (Figure 13). In addition, since there are no oil or natural gas reserves in the countries that have been identified or utilized, there are not any oil refineries that could be identified as a potential user of green hydrogen or biogas as fuel. For fuel demand Since

Lao PDR is not facing to the sea, and it has been depending on port facilities of its neighboring countries for importing oil and gas, as well as pipelines.

This reliance on imported oil and gas from neighboring countries for domestic demands including for transportation and households has resulted in a trade imbalance for Laos. This point is also demonstrated in a report by the Japan External Trade Organization (JETRO), a Japanese government-related organization in 2019, which showed that the export value was US$ 5,816 million against the import value of US$ 7,117 million, which results in US$ 1,301million trade deficit for Laos.[25]

On the other hand, as illustrated in the previous chapters of this report, Lao PDR has sufficient volume of renewable electrical power mainly derived from the hydro-power stations. According to MEM (Ministry of Energy and Mine), approximately 70% of electricity is generated by the hydro-power stations (the rest is mostly from coal thermal plants in addition to a small percentage of solar power plants). However, as stated in the previous chapter of this report, due to the overestimation of demand, there has been electricity surplus.

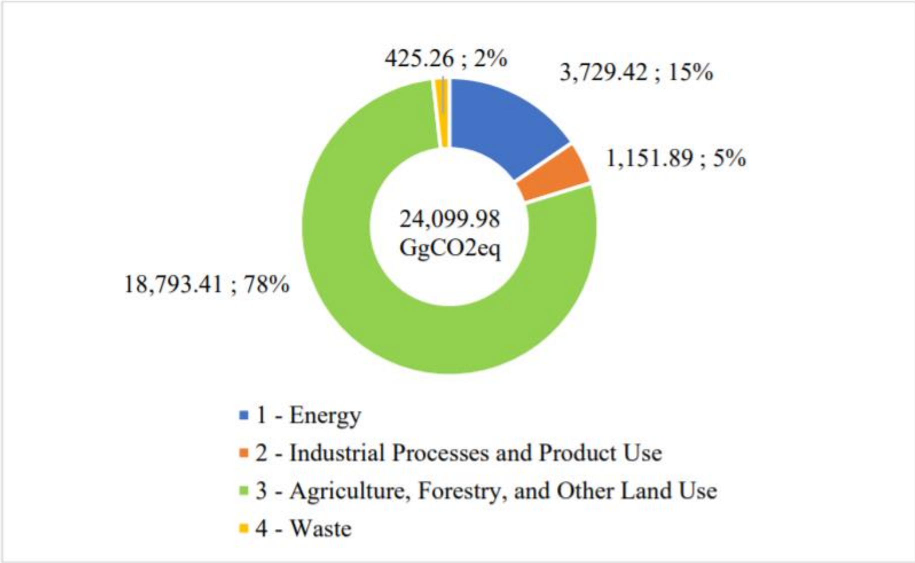
1.12 GHG Emissions from the Industry Sector

According to the first Biennial Report submitted to the United Nations Convention on Climate Change (UNFCCC) in 2020, the GHG emission from the industrial sector was 1,158,000 t-CO_2 eq, which is equivalent to 5% of the total GHG emission from the country[26]. The emission

[25] Japan External Trade Organization (JETRO). ラオス：概況・基本統計 (“Overview and basic statistics”). August 2021. https://www.jetro.go.jp/world/asia/la/basic_01.html
[26] The first biennial update report. Lao People’s Democratic Republic. https://unfccc.int/sites/default/files/resource/867493251_Lao%20Peoples%20Republic-BUR1-1-Draft%20Biennial%20Update%20Report-BUR_Lao%20PDR_24July2020.pdf

from the cement factories is 1,087,000 t-CO_2 eq, which accounts for nearly 95% of the emission from the industrial sector[27].

Figure 13. CO2 emission by sector in Lao PDR



1.13 CO2 Capture from the Cement Industry

As illustrated above, since there are little to significant no industrial, manufacturing, or oil/gas refinery activities in Lao PDR besides cement factories, which is also a major contributor to the GHG emissions from Lao PDR, it can be considered a primary source of CO2, which is required to produce methane via the process of methanation using the green hydrogen produced using water and electricity. CO2 from a cement factory can be captured by separating CO2 from exhaust gas by using either physical adsorption, physical absorption, chemical absorption, membrane separation, or cryogenic separation methods. In order to determine the most suitable CO2 separation method for a given cement factory, in terms of both technical and economic

[27] Ibid (p.20)

terms, the analysis of the following items (although not by any means exhaustive) should be conducted.

- Concentration of CO_2 in the source material
- Composition of the exhaust gas
- Existence and composition of impurities
- Scale of the cement factory
- Target CO_2 purity
- Optimum CO_2 concentration device

The amount of CO_2 that can be recovered from a typical cement factory in Lao PDR is difficult to estimate since it depends on the production scale, fuel type, the efficiency of the equipment as well as the CO_2 concentration in exhaust gas among others. For illustration purposes, according to one estimation, production of one ton of cement emits up to 622 kg of CO_2,[28] meaning that a cement factory producing 1,000,000 tons of cement per year, which is the case for the Langxan factory listed in the table 13, can potentially be emitting approximately 622,000 tons of CO_2 per year. By utilizing CO_2 from these factories, perhaps at a demonstration level but eventually scaling up to a commercial level, Lao PDR will be able to not only directly reduce the emissions from the cement factories, but also in other sectors since the green hydrogen or methane produced via the power-to-gas technology can be used as emission-free fuel.

Table 13. List of cement factories in Lao PDR

[28] Nature: https://www.imperial.ac.uk/news/221654/best-ways-carbon-emissions-from-cement/

No.	Factory Name	Location	Capacity (ton/year)
1	Luangphabang cement factory	Nam Bark District Luangphabang Province	350,000
2	Lao Vangvieng cement No. 1	Vangvieng District Vientiane Province	90,000
3	Lao Vangvieng cement No. 2	Vangvieng District Vientiane Province	240,000
4	Lao Vangvieng cement No. 3	Vangvieng District Vientiane Province	900,000
5	Thakaek cement factory	Thakaek District Xaythany District	900,000
6	Vangvieng cement factory	Somsavanh Village Xaythany District	120,000
7	Savannakhet Lao cement factory	Saphungkeo Village Ardsaphungthong District	150,000
8	Salavan cement factory	Salavan District Salavan Province	600,000
9	Factory of product cement of BMC limited	Xaythany District Vientiane Capital	500,000
10	Xiangkhuang cement factory	Khoun District Xiangkhuang Province	50,000
11	Factory of Cement Khounkham	Khounkham District Khammuane Province	1,000,000
12	Factory of Cement Xayaboury	Xayaboury Province	300,000
13	Construction Project of Oudomxay Cement Factory	Oudomxay Province	900,000
14	Construction Project of Cement Factory	Yommalath District Khammuane Province	1,600,000
15	Construction Project of Cement Factory	Hinoun District Khammuane Province	1,700,000
16	Cement Factory	Mahaxay District Savannakhet Province	1,800,000
17	Construction Project of Khounkham Cement Factory	Kaisonephomvihan District Savannakhet Province	300,000
18	Construction Project of Hinherb Cement Factory	Hinherb District Vientiane Province	900,000
Total capacity			12,400,000

Source: Lao Cement Association

1.14 Power-to-Gas Application

In the course of establishing the new strategy, it is important for Lao PDR government to put priority on energy independence, international trade balance and provide its people with the energy with the reasonable price.

Applying the power-to-gas to the "hard-to-abate" industries, such as the cement industry as discussed previously, either by using CO2 from cement factories or using hydrogen or methane as fuel, Lao PDR can potentially achieve carbon neutrality in cement sector, and eventually the industrial sector. This is because methane gas produced by power-to-gas application will generate CO_2 during combustion, however, it is considered "carbon neutral" as there is no CO_2 generated in the gas production process.

In addition to the cement industry, transport and transportation sectors can be a potential candidate to become the frontrunner in utilizing renewable methane and hydrogen as vehicle fuels. In fact, natural gas or CNG have been used as an alternative non-fossil fuel for motor vehicles for many years. Natural gas emits less CO2 in comparison to diesel or gasoline, hence it is considered one of the ways to reduce emissions from vehicles.[29] While, there are some studies that have found that natural gas or CNG vehicles are not adequate in eliminating GHG, this argument does not apply to methane produced by the P2G technology, therefore making it a more feasible candidate as a alternative fuel in helping the transport and transportation sector in Lao PDR achieving carbon neutrality.[30] Detailed analysis on the use of P2G technology in the transportation sector will be discussed in the next section.

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[29] M. Prussi, et al. Biomethane as alternative fuel for the EU road sector: analysis of existing and planned infrastructure. *Energy Strategy Reviews.* 2021; 33. https://www.sciencedirect.com/science/article/pii/S2211467X20301656

[30] Trivedi, et al. Current scenario of CNG vehicular pollution and their possible abatement technologies: an overview. *Environmental Science and Pollution Research*, 2020; 27(32). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7429099/

2 TRANSPORT SECTOR ANALYSIS

2.1 Analysis Outline

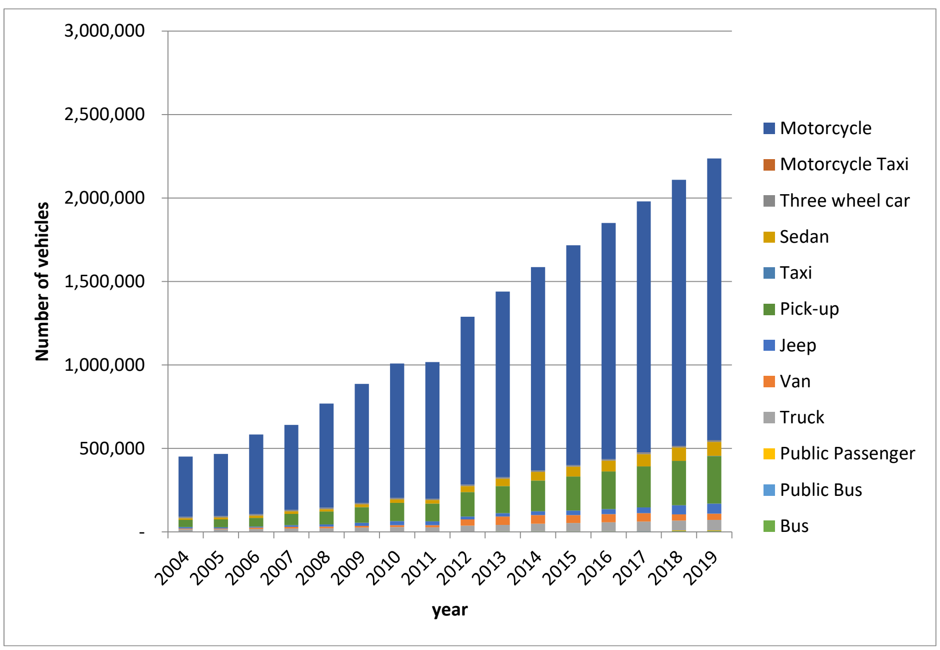
This report will analyze the overall current GHG emissions from the transport sector in Lao PDR by vehicle type (passenger cars, buses (by type including 12m-bus/mini-bus), two-wheel vehicles, and three-wheel vehicles. In addition, this report will also address the GHG emissions in 2030 from the transport sector for scenarios where biogas (e.g. synthetic methane) vehicles were was introduced as an alternative to gasoline vehicles.

2.2 Analysis of current and future estimates of vehicles

2.2.1 Number of vehicles by vehicle type

The number of registered vehilces by type from 2004 to 2019 is show in Figure 14. The total number of registered vehicles was 450,000 in 2004, which increased to 2,240,000 in 2019.

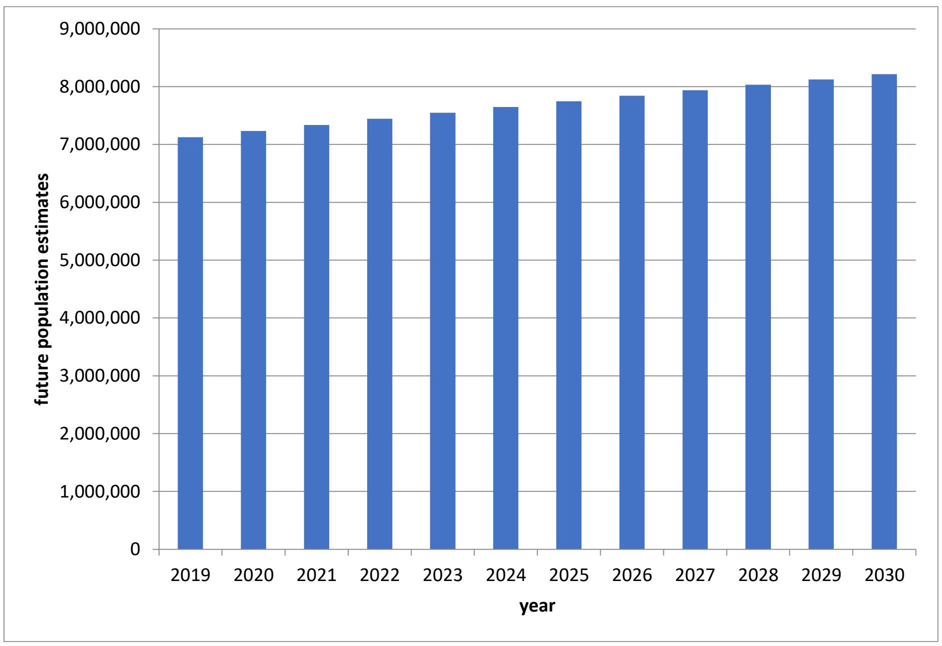
Figure 14 Number of vehicles by vehicle type in Lao PDR, 2004 - 2019



Source: MINISTRY OF PUBLIC WORKS AND TRANSPORT

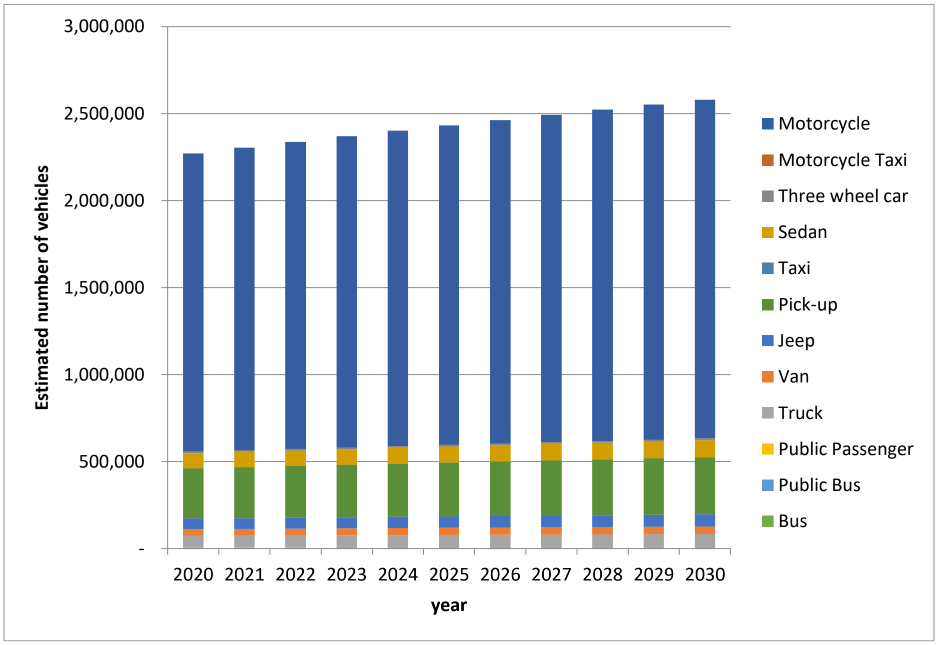
Because there is no official future projection of the number of vehicles in Lao PDR, this report a population growth projection is used to arrive at a total number of vehicles in 2030. Based on an assumption that the change in the number of vehicles corresponds with the change in population, the number of vehicles for each year is calculated using the population projection data from United Nations Population Fund (UNFPA) and Laos Statistics Bureau (LSB) from 2019 to 2030. The population growth projections by UNFPA and LSB are shown in the Figure 15, and the projection of number of vehicles calculated based on these data is shown in the Figure 16 and Table 14. For the population growth, the data shows 7,120,000 in 2019, and 8,220,000 in 2030, with a 115% increase. Based on this population growth assumption, the number of vehicles is 2,240,000 for 2019 and 2,580,000 for 2030 (Figure 3.3.1).

Figure 15 Population Future Estimates in Lao PDR, 2019-2030



Source: made by UNFPA/LSB

Figure 16 Future estimated number of vehicles by vehicle type in Lao PDR, 2020 - 2030



Source: Estimation by the project team

Table 14. Future estimate of vehicles in Lao PDR,2030

Vehicle type	Number of vehicles	
	2019	2030
Motocycle	1,688,224	1,946,984
Motorcycle Taxi	156	180
Three wheel car	9,001	10,381
Sedan	84,547	97,506
Taxi	396	457
Pick-up	284,384	327,973
Jeep	60,376	69,630
Van	37,622	43,388
Truck	63,330	73,037
Public Passenger	3,019	3,482
Public Bus	67	77
Bus	5,582	6,438
Total	2,236,704	2,579,533

Source: 2019 = Ministry of Public Works and Transport
2030 = Estimation by the project team

2.2.2 Fuel economy and distance by vehicle types, 2018

The average mileage and traveled distance by vehicle type are show in the Table 15. The average mileage for gasoline-fueled and diesel-fueled sedans is 9.6 km/liter and 9.5 km/liter, respectively. The average distance traveled was 15,000 km/year for gasoline-fueled sedans, and 16,000 km/year for diesel-fueled sedans.

Table 15. Fuel economy and distance, 2018

Vehicle type	Average KM/liter		Average KM/year	
2018	Gasoline	Diesel	Gasoline	Diesel
Motorcycle	20.50	-	5,104	-
Motor tricycle	10.00	-	15,974	-
Sedan	9.60	9.50	15,236	16,276
Pick-up	-	9.10	-	16,712
Mini Bus	-	9.20	-	18,206
Jeep (SUV)	9.90	9.30	16,006	16,995
Truck	9.80	9.80	31,633	14,080
Bus	-	3.40	-	4,990

Source: ERIA (2018)

2.3 Estimates for conversion to biogas (e.g. biomethane) vehicles

The projected number of compressed natural gas (CNG) vehicles[31], battery electric vehicles (BEV), and fuel cell electric vehicles (FCV) are shown in the Table 16. The number of these types of vehicles, excluding motorcycles and motor tricycles, in 2030 is 31,000 each based on the assumption that 5% of the gasoline-fueled vehicles of each type was replaced with CNG vehicles, BEVs, or FCV.

[31] See footnote 19 for the use of the term “CNG vehicles”.

Table 16. Estimate for conversion to biogas (e.g. biomethane) vehicles

Vehicle type	Number of vehicles								
	2019 (actual)		2030 (BAU)		2030 (P2G)				
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	CNGV	BEV	FCEV
rate	100%		100%		85%		5%	5%	5%
Motorcycle (+Motorcycle Taxi)	1,688,380	-	1,947,164	-	1,947,164	-	-	-	-
Motor tricycle (Three wheel car)	9,001	-	10,381	-	10,381	-	-	-	-
Sedan (+Taxi)	42,472	42,472	48,982	48,982	41,634	41,634	4,898	4,898	4,898
Pick-up	-	284,384	-	327,973	-	278,777	16,399	16,399	16,399
Mini Bus (Van)	-	37,622	-	43,388	-	36,880	2,169	2,169	2,169
Jeep (SUV)	30,188	30,188	34,815	34,815	29,593	29,593	3,482	3,482	3,482
Truck	31,665	31,665	36,519	36,519	31,041	31,041	3,652	3,652	3,652
Bus (+Public Passenger, Public Bus)	-	8,668	-	9,997	-	8,497	500	500	500
Total	1,801,706	434,999	2,077,860	501,673	2,059,813	426,422	31,100	31,100	31,100

* For sedan (+Taxi), Jeep (SUV), and Truck, the ratio of gasoline and diesel is assumed to be 1:1.

2.4 Examination of CO2 emissions and reductions

2.4.1 Outline of examination

In this chapter, the CO_2 emission reduction from replacing gasoline- and diesel-fueled vehicles with alternative fuel vehicles based on the data and projections presented in the Tables 14 to 16 in the previous chapter.

2.4.2 Calculation method of CO2 emissions

The CO_2 emission reduction in 2030 is calculated based on the following formula. More specifically, the CO_2 emission is calculated by dividing the average distance traveled by average mileage, and multiplying it by emission factor of gasoline and diesel in order to estimate the potential CO_2 abatement.

- Fuel Consumption [annual] X Emission Factor = CO2 emissions * By vehicle type
- Fuel Consumption = Number of Vehicles X Average KM/year / Average KM/liter * By vehicle type

(3) Calculation condition setting

1) Vehicles

The number of each vehicle type is as shown in the Table 16.

2) Fuel Economy and distance by Vehicle Types

The average distance traveled, and average mileage are as shown in the Table 15. These data are assumed to remain the same between 2019 and 2030.

3) Fuel type CO2 emission factor

The emission factor for gasoline and diesel are show in the Table 17, which is based on an ordinance stipulated by the Ministry of Economy, Trade and Industry, and the Ministry of the Environment in Japan [32].

For synthetic natural gas for CNGVs, the emission factor is estimated to be less than 85% of gasoline and less than 90% of diesel, according to the Japan Gas Association. For BEVs and FCVs, there is no CO_2 emission.

Table 17. Fuel type CO2 emission factor

	Fuel type	
	Gasoline	Diesel
CO2 emission factor	2.322 kg-CO2/l	2.619 kg-CO2/l

Source:「特定排出者の事業活動に伴う温室効果ガスの排出量の算定に関する省令」（平成 18 年経済産業省・環境省令第３号）(Ordinance on greenhouse gas emission calculation for designated emitters)

Table 18. CNG CO2 emission

CNG CO2 emission	Less than 82% in comparison to gasoline vehicles
	Less than 90% in comparison to diesel vehicle

Source: Japan Gas Association[33]

2.4.3 Results of examination of CO2 emissions and reductions

The CO_2 emission from the transport sector is as shown in the Table 19 and 20. The emission in 2019 is 3,567 t-CO_2, which will increase to 4,114 t- t-CO_2 eq in the business-as-usual scenario where no alternative fuel vehicles are introduced. In the scenario where CNGVs are introduced, the CO_2 emission is 3,802 t-CO_2 eq, which is 312 t-CO_2 eq or 8% less than that of the BAU scenario.

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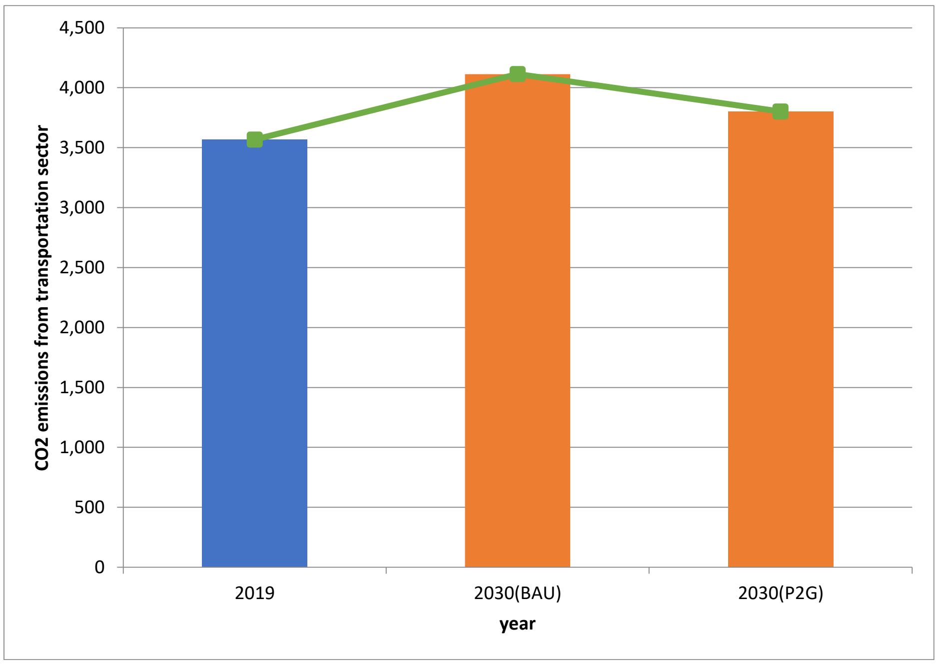
32 「特定排出者の事業活動に伴う温室効果ガスの排出量の算定に関する省令」（平成 18 年経済産業省・環境省令第３号 (Ordinance on greenhouse gas emission calculation for designated emitters). https://elaws.e-gov.go.jp/document?lawid=418M60001400003

33 Japan Gas Association. Natural Gas Vehicle Catalogue 2017. https://www.gas.or.jp/ngvj/pdf/ngvj_catalog_170818.pdf

Table 19. CO2 emissions from transportation sector

	2019	2030(BAU)	2030(P2G)
CO2 emissions from transportation sector	3,567,000 tons	4,114,000 tons Increase by 15% in comparison to 2019	3,802,000 tons Decrease by 7.6% in comparison to 2019

Figure 20. CO2 emissions from transportation sector



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[i] Decree on the Pilot Implementation of Digital Asset Transaction. No.888/MTC, issued on 9 November 2021.
[ii] The 2nd Meeting between the Lao PM's aides and JICA's experts in December 2021.