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Article

Scenario-Based Analysis of CO_2 Mitigation Potential in the Transport Sector: Comparison between Lao PDR and Thailand

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Abstract: This paper presents an analysis of CO_2 mitigation potential in the transport sector between Lao PDR and Thailand. The Long-rang Energy Alternative Planning (LEAP) model was used to forecast transport service demand, energy consumption and CO_2 emission of two selected countries during the period from 2010-2050. In this study, a stock vehicle turnover model was developed to assess the potentials of energy saving and CO_2 mitigation of policies relevant to the transport sector in Lao PDR and Thailand. For this analysis, three mitigation actions were selected, namely, 1) fuel switching, 2) advanced technology and 3) modal shift to reduce energy consumption and CO_2 emissions. Results of analyses show that, in the business as usual (BAU) scenario during 2010 to 2050 for Laos, it can save 9.4% of total energy consumption in 2050 while the cumulative CO_2 emissions will be reduced by 15% in 2050. For Thailand, the energy consumption in the transport sector will increase by approximately two folds. However, in CO_2 countermeasure scenario, the cumulative energy savings in 2050 will be approximately 5.2% while the cumulative CO_2 mitigation in 2050 will be about 14.6% when compared to the BAU scenario.

Keywords: CO_2 mitigation, LEAP, transport sector, Lao PDR, Thailand.

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1. Introduction

Transportation is the backbone driving the economy of a nation, which provides access to service for the masses of country and plays a vital role in determining the trend and pace of economic growth. The transport sector in many countries has significant impact on energy-related CO_2 emissions. It included exhibits of the energy security condition in those countries. Energy reduction and CO_2 mitigation are vital issues that many countries around the world and international organization are playing on it, especially for countries highly depending on imported oil [1, 2].

Laos and Thailand are two developing countries, located in Southeast of Asia, which have different characteristics in terms of economic development, along with their energy consumption and transportation landscape. In comparison with Laos, Thailand has high economic development. Its population is also higher than Laos. In 2010, Thailand has an approximate population of 66 million inhabitants [3] with a vehicle stock of approximately 28.5 millions [4], which is dominated by motorcycle and passenger cars. The total estimated passenger travel demand of Thailand in 2010 was about 270 billion passenger-kilometre (pkm) [5]. The fuels used are also highly diversified, where biofuels variants of gasoline and diesel, liquefied petroleum gas (LPG) and compressed natural gas (CNG) are widely used and promoted by the relevant government authorities of Thailand.

Unlike Thailand, Laos is a smaller country, with a population of approximate 6.5 million people. In 2010, the total number of vehicles registered in Laos reached 1 millions, which mostly dominated by motorcycle with a share of 80% [6]. Laos has a very primitive transportation system in terms of road transport when compared with Thailand; there are only two types of fuels. They are diesel and gasoline. Being a landlocked country, Laos depends heavily on road transport. The total travel demand of Laos in 2010 was accounted for 2.7 billion pkm and 0.6 billion ton-kilometre (tkm). The road transport was accounted for 95% of total pkm and 88% of total tkm [7]. The remaining passengers and freight traffics were carried through waterways and air transport.

Transport sector of both countries are important to the respective countries because they are significant emitter of CO_2 and are highly oil-consuming sectors. Thailand is the second largest energy consumption in Association of Southeast Asian Nation (ASEAN) countries [8] with a total final energy consumption of approximately 70,247 ktoe in 2010. Since Thailand began transforming from its agricultural-based economy to an industry one, the transport sector has become one of the largest energy consuming and CO_2 emitting sectors by sharing 35% to total energy consumption and contributing 26% to total CO_2 emissions in 2010 [9, 10]. Road transport is widely used mode and it is a major energy consumer in the transport sector where its energy consumption was accounted for 77% in the transport sector. Gasoline and diesel play vital role where their share was about 94.27% of total energy consumption in Thailand's transport sector. In terms of energy supply, Thailand has been depended on imported oil up to 60% of its total consumption and the rest is coming from domestic resources [11]. Laos has very small energy consumption when compared to Thailand with a total energy used about 2,312 ktoe. Transport sector is the major energy-consuming sector in Laos with a share of 22% of total final energy consumption. Road transport is the highest energy-consuming mode in the transport sector where its energy consumption was accounted for 98% and remainder is the air transport mode. Laos has a very primitive transportation system in terms of road transport where they are only diesel and gasoline, which play an important role in this sector and they are the main fuels which will be responsible for increasing CO_2 emissions in the transport sector. Since Laos does not have endogenous oil resources to meet its entire demand it is imperative to import petroleum from overseas countries. In 2010, the imported petroleum volume was accounted for 646 million litters.

Based on the above information, both countries have faced similar issues, mainly in terms of increasing trend of fossil demand in the transport sector. This trend would strongly impact on the reliability of future energy supply in the sector, along with energy-related CO_2 emissions. Therefore, the objective of this study is to examine energy savings and CO_2 mitigation potential of policies in both countries. The chosen mitigation actions are modal shifts, advanced technology penetration, bio-energy. The Long-rang Energy Alternative Planning (LEAP) model was used to forecast sector-wise transport demand until 2050. The base year is set as 2010 due to availability of related data.

2. Methodology

2.1. Data Collection and Estimate of Future Demand

The goal of this study is to investigate the energy consumption and CO_2 emissions in the transport sector under business-as-usual (BAU) scenario and different counter measures actions in Laos and Thailand. The estimation of sector-wise transport energy demand and CO_2 emissions were performed by using the long-rang energy alternative planning (LEAP) model. LEAP is a computer simulation program for simulation of costs and emissions from energy consumption, production and resource extraction for long-term planning by assessing the effects: physical, economic and environmental impacts of alternative energy programs, technologies, investments and actions [12, 13]. Fig 1 presents the methodology for Laos and Thailand in this study.

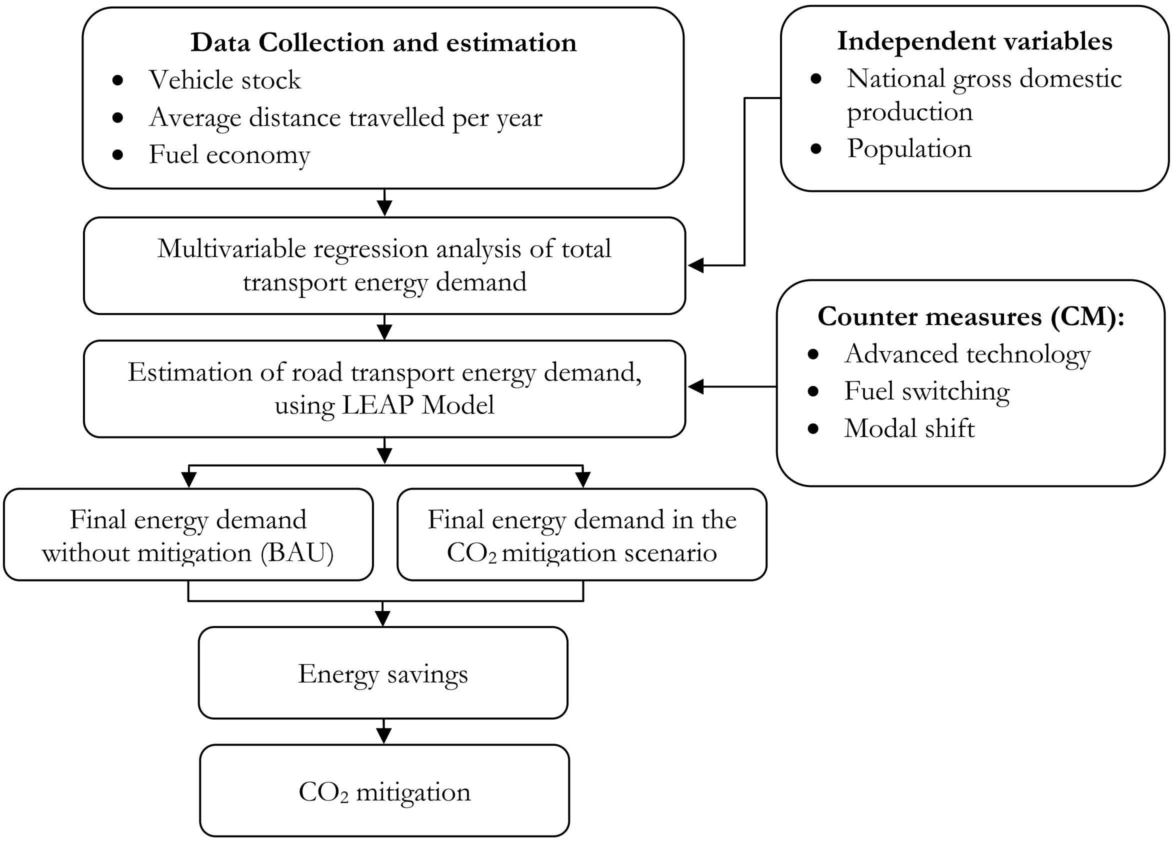

Fig. 1. Flow diagram of the methodology for estimation of energy savings and CO_2 mitigation.

In LEAP model, the transport sectors of Laos and Thailand are modelled and calibrated with the extent of details, nearly close enough to represent the actual system. In case of Thailand, data on vehicles and energy consumption have been obtained from Ministry of Land transport [4] and Ministry of Energy [10]. The GDP and population have been obtained from [3]. The road transport sector in Thailand is modelled as eight passenger vehicle types and two freight vehicle types. The passenger vehicle type includes motorcycles, motor-tricycles, small sedans, large sedans, passenger vans, taxis, buses and others. The freight vehicle types are pick-ups and trucks. The time horizon for the model is considered from 2010 to 2050.

For Laos, The historical data such as the number of vehicles and energy consumption have been obtained from government offices such as ministry of public works and transport, and the ministry of energy and mines. To meet energy performance; the important data such as the vehicle kilometer travel (VKT) and fuel economy were obtained from [14] and [15]. The number of vehicle types in the future years is estimated individually by linear regression function, which depends on socio-economic variables: the population and gross demotic product (GDP) of Laos.

2.2. Transport Demand Modelling

In this study, the BAU scenario acts as a reference case that helps to estimate and analyze the energy demand in the transport sector which will be expressed under the assumption where no policies or actions on energy savings and CO_2 mitigation. Along with the BAU, there is one another specific scenario that exists mitigation actions under countermeasures (CMs). In this study, three mitigation actions are selected under CMs. They are fuel switching, advanced technology, and modal shift actions. Fuel switching action is classified into two alternative fuels as gasohol (gasoline blended with ethanol) and bio-diesel (diesel blended with bio-oil). Gasohol includes E10, E20 and E80 (10%, 20% and 80% of ethanol blended with gasoline by volume). Bio-diesels consist of B5, B10 and B20 (5%, 10% and 20% of bio-oils blended with diesel by volume). The advanced technology scenario includes three technologies; hybrid vehicle (HB), pug-in hybrid vehicle (PHB) and electric vehicle (EVs) whilst, the modal shift will substitute motorcycles for buses and sedans, and substitute non-motorized transports, walking and bicycles, for motorcycles and buses.

The CO_2 countermeasures considered in this study are gathered from various literatures. The technological details relevant to efficiency improvement and vehicle technologies are considered with various degrees of technology categories, along with the suitability of the county such as infrastructure and economy condition. In this study, the share constraints of mitigation actions in the CMs scenario is designed and analysed in both countries, which considered technologies have been obtained from [5] ,[16], [17] and [18]. The average GDP growth rate during 2010-2030 is 4.11% and 5.92% for Thailand and Laos respectively, and during 2031-2050 is 2.70% and 4.30%. For the average population growth rate during 2010-2030 is 0.49% and 1.45% for Thailand and Laos respectively, and during 2031-2050 is 0.51% and 0.87% for Thailand and Laos respectively (see appendix). Table 1 shows the share constraints of mitigation actions in CMs scenario for both countries.

Table 1. The share constraints of mitigation actions in CMs scenario for Laos and Thailand.

Counter measures (CMs)	Maximum share constraints			
	2010	2020	2030	2050
Existing vehicles	100%	100%	100%	100%
Hybrid	0%	5%	10%	25%
Plug-in hybrid	0%	0%	5%	10%
Electric vehicle	0%	0%	5%	10%
Modal shift: non-motorized Transport	0%	5%	10%	10%
Modal shift – to bus	0%	3%	5%	10%
Fuel switching to renewable	0%	5%	10%	30%

3. Results and Discussion

This section presents the results of the transport demands for Laos and Thailand where the results for BAU and CMs scenarios are presented along the lines of energy consumption, and CO_2 emissions and mitigation. In addition, fuel compositions are also discussed.

3.1. Energy Consumption and CO_2 Emissions

Fig. 2 presents the energy consumption of the transport sector in Thailand in the BAU and CMs scenarios between 2010 and 2050. It can be seen that energy demand in Thailand's transport will increase from 19,552 ktoe in 2010 to 37,023 ktoe in 2050 with a total growth rate of 89%. By adopting the mitigations/countermeasures, the total growth rate of energy consumption will drop to 79% when compared to the BAU scenario in 2050. Meanwhile, the cumulative reduction of energy consumption in the CMs scenario accounted for 1,935 ktoe when compared to the BAU scenario in 2050.

Likewise, Fig. 3 shows CO_2 emissions in the Thailand's transport sector in the BUA and CMs scenarios. As seen in the energy consumption results (Fig. 2), CO_2 emissions also show the same trend due to increasing energy demand and high fossil fuel consumption, resulting carbon dioxide emissions will increase from 105.5 Mt-CO_2 in 2010 to 218.7 Mt-CO_2 in 2050. On the other hand, by adopting these counter measures it will result in decreasing CO_2 emission from 2.7% to 1.9% per year in 2050. It also can mitigate the carbon dioxide emissions by 14.6% in 2050 when compared with the BAU scenario. Fig. 2 shows the energy consumption, and Fig. 3 shows CO_2 emissions in the BAU and CMs scenarios in selected years for Thailand.

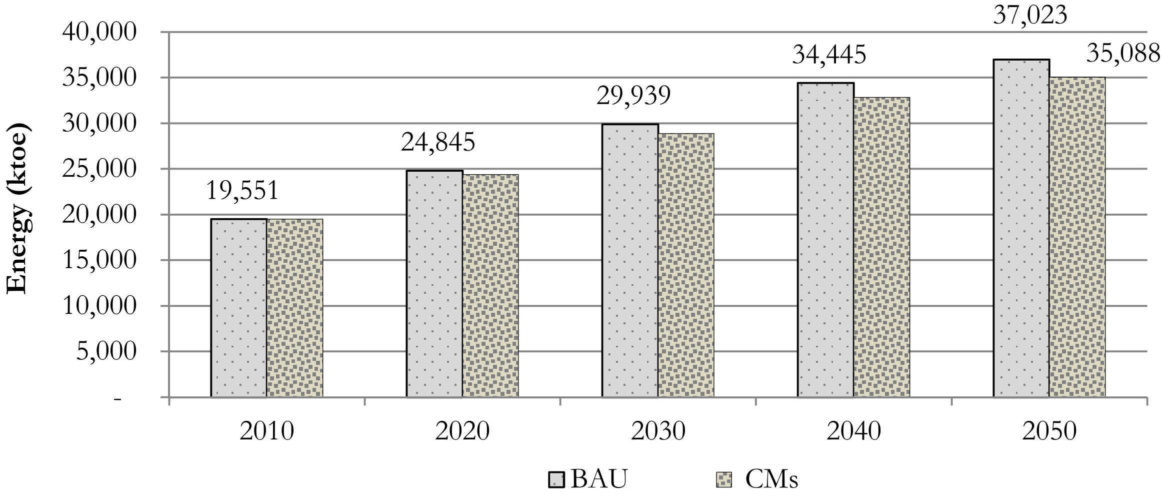

Fig. 2. Energy consumption in the transport sector in selected years for Thailand.

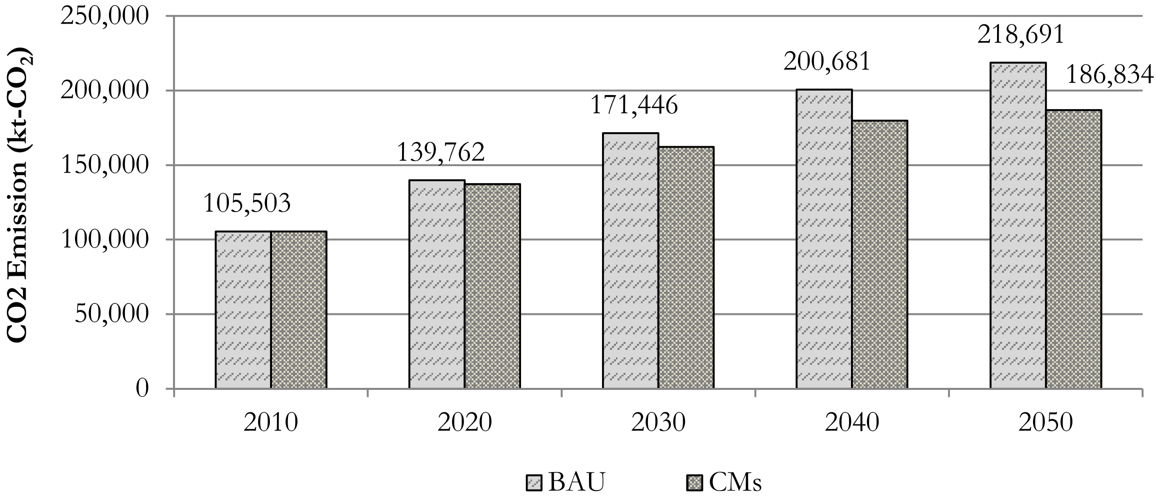

Fig. 3. CO_2 emissions in the transport sector in selected years for Thailand.

Fig 4 shows the energy demands in Laos. In the BAU scenario, energy demand will increase from 548 ktoe in 2010 to 2,823 ktoe in 2050 with a total growth rate of 425% when compared with the base year 2010. In the CMs case, the energy saving will be approximately 9.4% when compared with the BAU in 2050. CO_2 emission was 1,656 thousand tons of carbon dioxides in 2010 and will increased to 8,511 thousand tons in 2050 with total growth rate of 414%. By adopting the countermeasures, CO_2 emissions will be reduced with total growth rate of 338% where total CO_2 emission will be accounted for 7,247 thousand tons CO_2 in 2050 and the cumulative CO_2 mitigation will reach 15% against the BAU scenario during 2010-2050.

From the results, it can be seen that energy demand and CO_2 mitigation between Laos and Thailand are different because both countries have different socio-economic characteristics, which are the main drivers of transport demand in both countries.

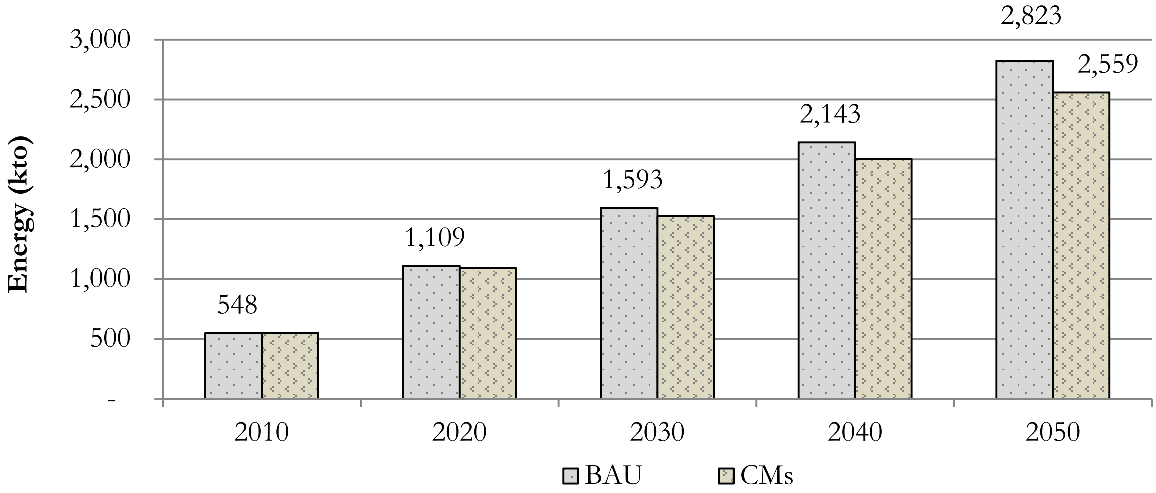

Fig. 4. Energy consumption in the transport sector in selected years for Laos.

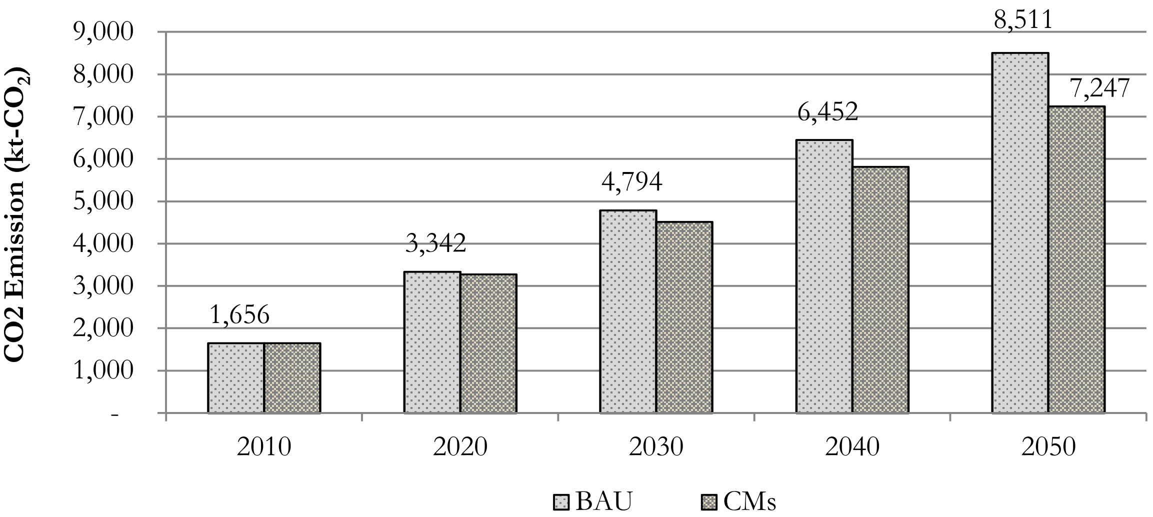

Fig. 5. CO_2 emissions in the transport sector in selected years for Laos

3.2. Fuel Composition

Table 2 and Table 3 show the fuel composition for road transport in Thailand and Laos. It can be seen that in the CMs scenario in the case of Thailand it is not as diversified as in the case of Lao because Thailand already has high diversified fuel mix. The CMs scenario also shows appearance of electricity in fuel mix due to electric vehicle diffusion. On the contrary, Lao road transport sector has only four fuel types. In the CMs scenario, gasoline will decrease from 26.7% to 20.3%. Furthermore, Biomass is dominated in the CMs case with a share of 7.9% while electricity shares of 0.6% in total final consumption in 2050.

Table 2. The fuel mix in the transport sector for Thailand.

Fuel type	BAU		CM
	BAU 2010	BAU 2050	CM 2050
Electricity	0.0%	0.0%	0.4%
Compressed natural gas (CNG)	8.9%	9.9%	8.7%
Gasoline	28.0%	30.9%	29.9%
Diesel	55.4%	50.4%	50.0%
Liquefied petroleum gas (LPG)	4.8%	5.8%	4.8%
Biomass	2.9%	3%	6.1%

Table 3. The fuel mix in the transport sector for Laos.

Fuel type	BAU		CM-L
	BAU 2010	BAU 2050	CM-L 2050
Electricity	0.0%	0.0%	0.6%
Gasoline	25.5%	26.7%	20.3%
Diesel	74.5%	73.3%	71.3%
Biomass	0.0%	0.0%	7.9%

4. Conclusion

This paper analyses CO_2 mitigation potential in the transport sector for Laos and Thailand by the effectiveness of policy packets/countermeasures (CMs) where they include the modal shift, fuel switching and advanced technology. The CMs scenario is modelled for Thailand and results show reduction in energy consumption and CO_2 emissions. The total energy consumption will increase from 19,551 ktoe in 2010 to 37,023 ktoe in 2050, with a growth rate of 89%. CMs scenario, the energy consumption in counter measures will be reduced by 1,935 ktoe resulting in CO_2 mitigation of 32 Mt-CO_2. For Laos, the total energy consumption will increase from 548 ktoe in 2010 to 2,823 ktoe in 2050, with a growth rate of 425%. In the CMs scenario, the energy consumption will be reduced by 264 ktoe resulting in CO_2 mitigation of 1.3 Mt-CO_2.

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Appendix

Table 1. Annual average growth rates of GDP and population for Thailand and Laos.

	Thailand	Laos	Reference
Average GDP (2010-2050)	3.4%	5.11%	**Thailand:** Thailand power development plan (PDP2010) **Laos:** Using Thai average growth rate due to similar GDP trend as shows in table 3
Average Population (2010-2050)	0.5%	1.16%	**Thailand:** Using average from 2001-2004, 2005-2010 to forecast the future population number **Laos:** United States Census Bureau, International Data Base (http://www.bluemarblecitizen.com/people/census-world-Laos)

Table 2. The number of foreign worker and shared foreign worker in Thailand and Laos in 2010.

	Thailand	Laos	Reference
Total foreign work	1,335,156	17,527	**Thailand:** National statistical office, Ministry of information and communication technology **Laos:** Lao bureau statistic report 2010 (http://www.nsc.gov.la/en/Statisticalyearbookall.php)
Total population	63,878,267	6,385,057	**Thailand:** Department of local administration, Ministry of interior **Laos:** Lao bureau statistic report 2010 (http://www.nsc.gov.la/en/Statisticalyearbookall.php)
% shared foreign workers	0.02%	0.0027%	