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Low carbon society scenario analysis of transport sector of an emerging economy—The AIM/Enduse modelling approach

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HIGHLIGHTS

- Thailand transport sector has been modelled using AIM/Enduse model.
- Potential cumulative mitigation of CO_2 during 2010–2050 is approximately 30% when compared the BAU scenario.
- Abatement cost curves show that various counter measures are practical in the transport sector.
- Energy security is enhanced due to CO_2 mitigation in the LCS scenario.

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ABSTRACT

The transport sector of a country is the backbone driving the economy forward. Thailand's land transport sector is modelled using the AIM/Enduse, which is a recursive dynamic optimization model, based on bottom-up modelling principle. The travel demand is divided into two major categories which are passenger travel and freight travel. The objective of this paper is to analyse the mitigation possible through low carbon society (LCS) measures and emission tax (ET). Two scenario clusters are devised along with the BAU case. The LCS scenario cluster has three designed scenarios which are LCS-L, LCS-M and LCS-H. The emission tax (ET) cluster has four scenarios, where the taxes of 50, 100, 200 and 500 USD/t-CO_2 are implemented. Along with this the marginal abatement costs (MAC) of the counter-measures (CMs) and the co-benefits in terms of energy security, productivity and air pollutant mitigation are also assessed. Results show that LCS scenarios are possible of mitigating up to 1230 Mt-CO_2 cumulatively, from 2010 to 2050. In terms of MACs, new vehicles play a pivotal role, along with hybrid vehicles. The Average Abatement Cost (AAC) assessment shows that the AAC of LCS-H scenario is in the order of 100 USD/t-CO_2. All the LCS and ET scenarios show an enhancement in energy security and also a threefold increase in productivity. There is distinct mitigation in terms of air pollutants from the transport sector as well.

1. Introduction

The transport sector of a country, along with its infrastructure serves as the backbone to mobility. It facilitates the movement of goods, services, labour and entrepreneurship which is vital to the social and economic well-being of a country. That being said, in modern times, with the dependence on oil for most modes of transport, this sector is becoming more and more important. Naturally governments of countries strive to facilitate the smooth functioning of the sector whilst mitigating the risks associated with the energy needs of that sector.

The transport sector has also grown in importance as one of the large energy consuming sectors. In most countries, oil and its by-products, and imported oil, since indigenous resources are not sufficient, are used in copious quantities to enable the functioning of the sector. In addition to this, the combustion of energy resources also brings about the concern of emissions of carbon dioxide and other greenhouse gases which lead to climate change.

Thailand is a vibrant economy which has been consistently classified as an 'emerging economy' by many monetary and trade institutions. As a non-Annex-I member country party to the Kyoto Protocol, it is under no obligation to reduce its CO_2 emissions. Yet, as a responsible member of the ASEAN community, Thailand is taking actions to reduce CO_2 emissions. Most CO_2 emissions in Thailand ensue as a result of energy use/combustion. As such, the transport sector of Thailand is a high emission sub-sector. In 2005,

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approximately 30% of the total final energy use was consumed in the transport sector, which resulted in 30% of the CO_2 emissions, of the total emissions from the energy sector. In 2010, this number came down to 27%. But, another significant aspect to be noted is the dependence of the Thai transport sector on oil. In 2005, of the total oil products used for energy related sectors, only 72% was used for transportation. This increased to be 77% in 2010. Also, the total amount of CO_2 emissions in the transport sector has been increasing since 2005, albeit at a slower rate in the near past. In addition to this, due to increasing urbanization the decade leading up to 2010 saw a rapid increase in road-based transport increase. In 1990, the number of sedans was approximately 777,000 and this rose up to 2.1 million in 2000 and more than doubled, to 4.5 million in 2010. Likewise, the number of pick-ups was 925,000 in 1990, which increased five-fold, to be 4.9 million in 2010. These were the main reasons for CO_2 emissions to increase along with energy consumption. These effects and changes did not happen in isolation. Most of this was due to the macro-economic changes that were happening to the economy of Thailand. In 1990, the secondary sector contributed 34.3% to its total GDP, but by 2010, the same contribution had risen to 37.4%. This, coupled with increasing affluence, was a major reason for rapid increase in the number of personal vehicles.

Yet, if Thailand is to meet its growth aspirations, it is imperative it looks at leapfrogging carbon intensive development pathways and strongly leans towards LCS measures.

Thailand's transport sector and especially the land transport sector, which is responsible for 90% of the emissions and energy use, has been the focus of emission reduction studies.

But, none of these works go into depth in terms of the counter-measures and the different mitigation drivers. Hence, in order to fulfill this gap, the authors decided to carry out the research study focusing on the land transport sector in Thailand, where LCS measures and emission tax as policy drivers are examined.

The primary objective of this research paper is to quantify the carbon emission mitigation possible through low carbon measures and through emission taxation in the Thai transport sector and also assess related co-benefits which accrue through emission mitigation. The secondary objective is to present preliminary techno-economic appraisals of the mitigation counter-measures (CMs). The transport sector of Thailand is modelled using the Asia-Pacific Integrated Model (AIM) Enduse model, which is a bottom-up recursive dynamic optimization model. The land transport sector is divided into passenger travel modes and freight travel modes. The timeframe selected in this research study is 2010–2050.

The rest of the research paper is organized thus: Section 2 presents a brief literature survey carried out in terms of LCS, co-benefits and relevant techno-economic analysis suited to this research study. Section 3 presents the methodology employed; Section 4 presents the results and finally Section 5 presents the meaningful conclusions that can be arrived at and further points for discussion.

2. Literature review

This section presents a brief literature review of the relevant subjects tackled in this research paper.

2.1. Low carbon society

Low carbon society (LCS) or low carbon concept, is the concept of an economy which has minimal output of greenhouse gas (GHG) emissions (SIIT, A. NIES Japan, 2010). Of recent times, low carbon development, and low carbon CMs have also been espoused by various governmental and supra-national developmental organizations.

The LCS concept came into being as certain developed countries recognized that the path the world is taking in terms of rampant resource use and consumerism would lead to greater destruction and environmental degradation (LCS-RNET, 2009). Japan and Europe embraced the LCS concept and many policy papers have been published, outlining the methods (Ministry of Environment, Japan, 2007) and ways whence LCSs can be achieved (Energy Conservation Fund, 2010; National Institute for Environmental Studies, Kyoto University, Ritsumeikan University, 2008). In addition to LCS concept being adopted into a quantitative one with mitigations quantified along with the different policy pathways, in reality LCS was meant to indicate a holistic concept, where sustainability and rational use of resources were also adopted as ways of life, leading to a better quality life, overall. The LCS was not just meant to indicate lower emissions in the energy sector or other emission sectors, but rather was meant to imply a concept which would improve overall livability of people in societies. Yet, as modellers and policy makers, it was important to also give quantifiable benefits and as such research was carried out starting with emission sectors.

Most of these texts on energy sectors, start with simple and already existing technologies, since reliance on non-nascent 'silver bullet' technologies is not a sustainable method of planning for the future (Energy Conservation Fund, 2010). That being said, of late, the focus has been on developmental organizations trying to persuade and cajole 'emerging economies' into leapfrogging carbon intensive technologies and infrastructure (IGES J. and TGO, 2010; Project, L.-C.A.R., 2012).

As of July 16th 2012, Thailand has been classified as an 'emerging economy" by the International Monetary Fund (International Monetary Fund, 2012). Hence, much attention has been paid to Thailand in terms of Low Carbon activities. Many organizations have carried out seminal work, such as (IGES J. and TGO, 2010; SIIT, A. NIES Japan, 2010; Sirindhorn International Institute of Technology et al., 2013; Winyuchakrit et al., 2011). Also, research connected to LCS is continuing to be of focus as well.

Some of the quantitative national level studies that have been carried out are: (Gomi et al., 2011; Kainuma et al., 2000; Nakata et al., 2011; Shrestha et al., 2007; Shrestha and Shakya, 2013; Winyuchakrit et al., 2011). There have been conceptual and analytical models presented in international for a that have been very useful for country-level implementation of low carbon measures and assessments (IGES et al., 2011; Parthan et al., 2010).

But as an in-depth look at these literatures reveal, there is very little sectoral level numerical analysis of carbon mitigation. As an emerging economy, Thailand already mirrors certain characteristics of developed or OECD countries. There is elevated use of private passenger modes and higher disposable income levels have lead to private passenger vehicles being seen as an aspirational symbol. Also the rampant economic growth seen in the previous decades have also contributed to road-based transport model being implemented in the country (Asian Development Bank, 2011). Works such as (Sirindhorn International Institute of Technology et al., 2013) do give the quantitative analyses of carbon mitigation in Thailand with respect to an LCS perspective, yet meaningful techno-economic analysis of such mitigation measures are beyond the scope of that work.

In terms of carbon mitigation in Thailand, there is an existing body of work which is large enough to act as a preliminary starting point. The transport sector of Thailand has been the focal point in works such as (Chollacoop et al., 2011; Limanond et al., 2011; Pongthanaisawan and Sorapipatana, 2010, 2013; Timilsina and Shrestha, 2009). But these works lack any sort of techno-economic analyses which are vital for any policy maker to seriously