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Assessment of long-term low emission power generation in Sri Lanka and Thailand

Sujeetha Selvakkumaran, Bundit Limmeechokchai *

Sirindhorn International Institute of Technology, Thammasat University, Thailand

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ABSTRACT

The environmental aspects related to the energy sector are of importance in the emission-constrained world of present times. The objective of this study to assess the effects of Low Carbon Society (LCS) on the Thai and Sri Lankan power systems, in terms of CO_2 mitigation, and energy security and other techno-economic results, such as marginal abatement costs. This study models the power sectors using a bottom-up optimization model called AIM/Enduse. The crux of the analyses is carried out using scenarios. Along with the LCS scenario, this study also considers a LCS scenario without the availability of Carbon Capture and Storage (CCS), and has two separate scenarios with emission taxes of 50 USD/t-CO_2 and 100 USD/t-CO_2 on the power generation. Results show that there is a cumulative mitigation of 1.4 Gt-CO_2 in the LCS scenario during 2010–2050, when compared to the BAU case for Thailand. Also, the effectiveness of the LCS scenario without CCS, known as the LCS/CCS scenario, is considerably reduced in the Thai power sector. The LCS scenario also has higher energy security, and better economic benefits. The LCS scenario in the Sri Lankan (SL) power sector has a cumulative mitigation of 166 Mt-CO_2. The reduction in effectiveness of the LCS/CCS scenario in SL is not as drastic as the Thai power sector. The need of CCS for Sri Lanka is much reduced. The Marginal Abatement Costs (MAC) show that CCS technology plays a vital part in the Thai power sector and helps reduce the average abatement cost. This holds true in the case of the Sri Lankan power sector as well, yet not to the extent of the Thai case.

Introduction

The power system is one of the vital links in developmental strategies. Energy and the provision of an efficient and usable energy carrier are important in terms of enabling growth of a country. The developing countries are at a crossroad as to conflicting objectives. On the one hand they have to aim to be more competitive in terms of economic growth and wellbeing, but on the other hand, they are faced with challenges in procuring energy sources, which aid in propelling them towards economic security. Thailand and Sri Lanka are two developing countries at such a crossroad. This study looks at the long term de-carbonization of their power sectors.

Background

The power sector is an intermediate and derived energy sector and as such, is very important for many aspects to both Sri Lanka and Thailand. The Sri Lankan power sector is riddled with much inefficiency, as it implicitly still relies on old power generation units which run on diesel and naphtha [1]. In addition to this, the power sector is affected by the vagaries of weather as almost half of the installed capacity is of major hydro variety. The generation expansion plan put out by the electricity generating authority of Sri Lanka (Ceylon Electricity Board – CEB) outlines plans for coal power plants to be built and incorporated into the grid [2]. Even though one of this coal power plant was built in 2012, as of 2013 it had not been commissioned, since the power plant has been plagued by problems of a technical nature [3]. The plan also outlines renewable power plants to be incorporated into the grid [1]. There are plans in place to invest in biomass based dendro (biomass based) power plants, along with solar PV units and small and micro hydro projects. In addition to this, it should be mentioned that there are no explicitly mentioned plans in place for the Sri Lankan power sector.

The Thailand's power sector is better suited and more modern in comparison to Sri Lanka. But right now it is heavily dependent on NG, and as such expends a lot of its economic earnings to purchase NG from neighbouring countries. The Electricity Generating Authority of Thailand (EGAT) [4] has published its power generation expansion plan and this plan has incorporated renewable

* Corresponding author.
E-mail address: bundit@siit.tu.ac.th (B. Limmeechokchai).

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power supply as well. These renewable sources are incorporated into the grid via small and very small power producers' scheme [5].

In both Sri Lanka and Thailand, in the past years, the carbon intensity of energy and electricity has been increasing. This is due to the introduction of coal power plants (See Figs. 1 and 2 in Appendix). Hence, the onus is on both the countries to stop the CO_2 emissions from ballooning in the future.

The primary objective of this research paper is to analyse the effects of LCS measures on the power sectors of Thailand and Sri Lanka, under the BAU case and LCS case with and without Carbon Capture and Storage (CCS) mitigation technology. Along with this, two emission tax regimes on the power sector would also be assessed, where the efficacy of emission taxes as mitigation drivers are compared with the LCS scenarios. The analyses of the temporal effects on the techno-economic parameters of the power sectors of these two countries are also presented.

Also, the temporal change of the power sector and along with it, the energy security is also to be assessed in this research study. Another co-benefit to be assessed is the reduction in local air pollution brought on by the power sector. The reason for selecting Sri Lanka and Thailand as the two developing Asian countries is that even though they have differing sets of power sectors at this current time, in another 10-year time in future, Sri Lanka is expected to have ambitions of reaching the same developmental stage as that of Thailand. It serves well to analyse the effects of CO_2 mitigation on countries at different stages of growth and to also assess how the LCS and emission tax regimes affect CO_2 mitigation. The power sectors of Sri Lanka and Thailand are modeled using Asia-pacific Integrated Model (AIM) Enduse, which is a recursive dynamic optimization model with a bottom-up modeling structure [6]. The time horizon for this modeling exercise is from 2010 to 2050.

Literature review

This section gives the literature review carried out during the research study which has culminated in this research paper. This section is divided into three main sub-sections: the historical perspective of Low Carbon Society, low carbon assessment parameters and low carbon technologies, specifically carbon capture and storage (CCS).

Low Carbon Society

A Low Carbon Society (LCS) or a low-fossil-fuel economy is a concept that refers to an economy which has a minimal output of GHG emissions into the biosphere, but specifically refers to the GHG of CO_2 [7]. Of present times, much has been said about LCS and Low Carbon Development (LCD) and many research organization and academic think-tanks are spending time scripting and modeling energy systems so as to conclude how a Low Carbon future would look [8,9]. The three main precepts which are outlined as being essential to creating a LCS are

- Carbon minimization in all sectors.
- A simpler life style that realizes better quality of life.
- Coexistence with nature.

It is interesting and of scientific pertinence to look at the chronology of development of the LCS concept, in the developed and developing world alike. The early years of the '00 s decade saw the advent of the start of the LCS as a concept, with Japan and UK expressing interest in voluntary emission reduction targets. Preliminary first drafts were prepared and presented [10]. Later, these drafts acted as the starting point of actual policy. At the same time, there was concurrent work that was also carried out in Europe [11] and the UK [12]. As time went by, research work permeated into the mainstream sphere, and more developing Asian countries also got recruited into the LCS study programme. Countries such as Thailand and Malaysia are some of the few countries that initiated the LCS thinking strategies amongst developing Asian countries.

Along with the permeation of the concept of LCS, research organizations were also concentrating on developing tools which would help with the visualization and conceptual modeling of how various systems would be affected by implementing or attempting LCS in countries. Many diversified computer models and integrated assessment models were devised as a result of satisfying the need for such scientific analysis [11,13].

The SIIT et al. [14] gives the basis and the modeling methodology behind the policy package recommended for carbon mitigation or LCS initiatives in Thailand. The researchers have used two energy modeling tools, namely AIM Enduse and AIM Extended Snapshot to model the Thai energy sector and their recommendations are that Thailand should focus on counter-measures in the industry, commercial and transport sectors and help with the penetration of renewable energy. The report also gives a policy package, outlining the policy measures in residential and commercial sector, electricity generation sector, transport sector and industrial sector. The policy measures for electricity generation are given as: subsidy in investment for energy efficient equipment, promotion of technology transfer, promotion of renewable energy utilization, fuel switching, and reduce own usage and transmission loss.

The Ref. [10] was one of the first attempts by Japan at incorporating Low Carbon thinking into policymaking. The main objective of attempting LCS measures is to reduce the CO_2 emissions in 2050 to be half of that of 1990 levels, as was explained in this literature. Another important point made in the presentation is that even though numerical quantification is important, at the beginning it is imperative that 'story lines' of plausible scenarios are devised.

Whilst the authors understand the importance of considering LCS as a holistic concept (the first point mentioned, where carbon minimization should take place in all sectors), if researchers were to consider all sectors this will lead to a large research scope and would take an inappropriately long period of time. Hence, even with the understanding that LCS is a broad concept this research study would be limited to carbon minimization in the power sector. In conclusion, the LCS concept is one which is very important to assessing and inculcating carbon mitigation, both quantitatively and qualitatively.

Low carbon assessment parameters

Energy security

The contemporary energy vision of nations is discussed in [28]. Five major challenges identified by the work are: increasing energy consumption levels, lack of energy access, environmental risks, energy security and a focus on the long term context.

The environmental risks are framed with a portfolio of supply side options focusing on low-carbon energy from non-combustible renewable, bio-energy, nuclear energy and CCS. Another important need is the increasing requirement for storage and back-up technologies, for example natural gas backup and smart grids to support integration of wind and solar energy. Other important facets of technological advancement, such as nuclear energy integration, growth of second generation bio-energy, fossil fuel coupled with CCS and aggressive de-carbonization are required for LCS and in turn impact upon energy security.

Exploring perceptions about energy security is the main objective in [15]. Energy security is defined as 'equitably providing available, affordable, reliable, efficient, environmentally benign,