Energy Policy 38 (2010) 2586–2597

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Co-benefits of CO_2 emission reduction in a developing country

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ARTICLE INFO

Article history:
Received 9 June 2009
Accepted 6 January 2010
Available online 9 February 2010

Keywords:
Carbon reduction targets
Co-benefits
Effects security

ABSTRACT

In this paper, we examine the co-benefits of reducing CO_2 emissions in Thailand during 2005–2050 in terms of local pollutant emissions as well as the role of renewable-, biomass- and nuclear-energy. It also examines the implications of CO_2 emission reduction policy on energy security of the country. The analyses are based on a long term energy system model of Thailand using the MARKAL framework. The study shows that the power sector would account for the largest share (over 60%) in total CO_2 emission reduction followed by the industrial and transport sectors. Under the CO_2 emission reduction target of 30%, there would be a reduction in SO_2 emission by 43% from the base case level. With the CO_2 emission reduction target of 10–30%, the cumulative net energy imports in the country during 2005–2050 would be reduced in the range of over 16 thousand PJ to 26 thousand PJ from the base case emission level. Under the CO_2 emission reduction targets, the primary energy supply system would be diversified towards lower use of coal and higher use of natural gas, biomass and nuclear fuels.

1. Introduction

Climate change policies are, although, primarily intended to reduce Greenhouse gas (GHG) emissions, often have other benefits, usually named as co-benefits and ancillary effects[1] (IPCC, 2007, 2001). The fact that there is a linkage between mitigation of GHGs and local air pollution is already accepted (IPCC, 2007). That the climate friendly technologies and resources reduce not only GHGs but also the local pollutant emissions provide impetus for adoption of cleaner fuels and advanced technologies. Thus, inclusion of the co-benefits can have significant impacts on the cost effectiveness of the climate policy. Likewise, the cost of controlling local or regional air pollutants might be reduced if these are combined with GHG mitigation policies (Van Harmelen et al., 2002). Caspary and O'Connor (2002) suggested that the co-benefits in developing countries are probably more significant than those in developed countries and emphasized on the requirement of such study for making informed decisions.

Most studies on co-benefits and ancillary effects of GHG mitigation policies are conducted for developed countries, particularly the US and Europe (Barker and Rosendahl, 2000; Davis et al., 2000). Since developing countries are not obliged to reduce GHG emissions, studies in evaluating co-benefits of GHG mitigation policies in developing countries are lacking (Creutzig and He, 2008). For the fast developing countries like Thailand, the evaluation of the co-benefits of GHG mitigation policies would provide a basis for a more comprehensive economic and environmental analysis. Such an evaluation would also assist in integrating climate change mitigation policies with the sustainable development strategies of the country.

Thailand is the second largest economy among the countries in the Association of South East Asian Nations (ASEAN) (IMF, 2008) as well as the second largest emitter of CO_2. The country is heavily dependent on imported energy in that the imported energy accounts for about 55% of the total primary energy supply in the country in year 2005 (DEDE, 2006a). With the economy growing at over 5% per annum and increasing urbanization, the CO_2 emission in the country is expected to grow significantly in the future.

There are some studies on GHG emissions in the case of Thailand, (Shrestha and Pradhan, 2008a; Shrestha et al., 1998, 2007, 2008b; Limmeechokchai and Suksuntornsiri, 2007a, 2007b; Tanatvanit et al., 2003, 2004; NEPO, 1999). Santisirisomboon et al. (2001) analyze the effects of carbon tax in the power generation sector of Thailand. Timilsina and Shrestha, 2002 and Malla and Shrestha (2005) analyze the effects of carbon tax on the Thai economy using a general equilibrium framework for the period of 2000–2030. Shrestha and Pradhan (2008a) and Shrestha et al. (2008b) analyze the effect of carbon tax for the period of 2000–2050. However, these studies did not examine the co-benefits of CO_2 reduction comprehensively for a period of 2005–2050.

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[1] The term "co-benefit" is referred as intentional benefits of policies, e.g. reduction of conventional air pollutants as a result of a climate change mitigation policy. The term "Ancillary effect" is referred ancillary physical effects evaluated in terms of monetary values. See IPCC (2001), O'Connor (2000) and Davis et al. (2000).

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doi:10.1016/j.enpol.2010.01.003

In the present study, we examine the prospects for CO_2 reduction from the Thai economy during 2005–2050 under three CO_2 emission reduction targets taking two analysis periods (i.e., 2005–2030 and 2005–2050). We analyze the co-benefits of the emission reduction targets in terms of the reduction of local air pollutants (NO_x and SO_2) and energy security of the country. We also examine the effect of the CO_2 emission reduction targets on the development of renewable energy and use of nuclear energy. A bottom–up least-cost energy system optimization model of Thailand was developed based on the Market Allocation (MARKAL) modeling framework (ETSAP, 2007).

The paper is organized as follows: Section 2 describes the methodology used in the study. Section 3 provides descriptions of the reference (or base) and emission reduction scenarios. The description of the reference case analysis is presented in Section 4 followed by an analysis of the effects of CO_2 emission reduction targets on energy security and air pollutant emission reductions and other co-benefits i.e., introduction of cleaner energy use in the power and transport sectors, improvement in efficiency of power generation, and adoption of efficient appliances in residential sectors in Section 5. The final section presents the key conclusions and final remarks as well as policy implications of the study.

2. Methodology

The study uses a bottom–up least cost optimization energy system model of Thailand that was developed for the study using the MARKAL framework. The model computes an inter-temporal partial equilibrium on energy markets, i.e., it ensures that the supply meets the given demand at a given set of prices of all energy forms at each time period with an assumption of possessing complete foresight in a competitive market (Loulou et al., 2004). This type of model is used in several studies on energy and CO_2 emission analysis at country and global levels (Rajesh et al., 2003; Strachan and Kanan, 2008; Seebregts et al., 2005; Smekens-Ramirez Morales, 2004; Remme and Blesl, 2008).

The model selects both the supply- and demand- technology mix that minimizes the discounted cost of the energy system under a set of resource and demand constraints. The energy system includes primary energy resources (includes mining, extraction, etc.), secondary fuels (refining, power generation, etc.), final energy and energy services. The primary energy resource component includes coal mining, natural gas extraction, crude oil extraction and import and export of these fuels. The conversion of primary fuels to secondary fuels takes place through refinery and power generation. For power generation, 80 existing and 36 new technology options are considered. Among the new technology options considered, there are coal, lignite and natural gas based carbon capture and storage (CCS) technologies. Other emerging technology options includes clean coal technologies (such as IGCC, PFBC), fuel cell vehicles, hybrid electric vehicles and plug-in hybrid electric vehicles besides conventional technology options in different sectors. It also includes bio-fuel (10% bio-ethanol mixed with 90% gasoline and 10–20% bio-diesel mixed with 90–80% diesel) as an energy resource option in the transport sector. Flex-fuel vehicles using up to 85% ethanol are also considered in the present analysis. We have considered nuclear energy as an energy option for power generation and six potential nuclear power generation technologies in the future are considered in the present analysis.

In the demand side, we have divided the Thai economy in five main sectors, namely, agriculture, commercial, industrial, residential and transport (NEPO, 1999). DEDE (2006b) has treated energy consumption in mining, manufacturing and construction as separate sectors; however, in this paper, we have categorized them as sub-sectors of the industrial sector. The industrial sector has been sub-divided into various sub-sectors, i.e., cement, steel, sugar, paper, chemicals, food, equipment, textile and others. Similarly, transportation is sub-divided into passenger and freight transportation. The passenger transportation is further divided into road, rail, air and water transport. All trading enterprises, hotels, restaurants, financial and telecommunication establishments are included in the commercial sector. The residential sector has been divided into urban and rural categories. Altogether 248 existing and candidate technology options are considered for meeting end-use service demands. The future projections of service demands in agriculture, commercial, industrial and freight transport sectors are based on sub-sectoral value added, while the projection of service demands in the residential sector is based on number of households and appliance ownership per household. The service demand for passenger transport is projected based on the population growth. Thailand's GDP projection during 2005–2016 is based on TDRI (2004), according to which the GDP would be growing at 6.4% by 2016. Thereafter, it is assumed that the GDP will grow at the rates of 6.4%, 5.3% and 4.5% per annum during 2016–2030, 2030–2040 and 2040–2050, respectively. On population, the medium variant forecast of the UN (2004) is considered in the model. Although there is a possibility of decoupling of economic development and service demands over a long run, we have assumed that the service demand in a given year is linearly proportional to the value added in the year due to lack of studies as to the possible timing of such decoupling.

3. Scenario description

In the study, four scenarios are considered—the base case and three alternative scenarios. The base case in the present study is the scenario based on the presently available information and future plans and policies (e.g. government policies in energy, environment and economy) that may influence the energy demand and supply in Thailand. It includes the energy carriers and technology options, which are presently being used in Thailand. The cost parameters of these technologies are based on CGER-NIES (2007). Also different emerging technology options like bio-fuel, hybrid fuel vehicles and carbon capture and storage (CCS) and possible future energy carriers like nuclear and fuel cell are considered in the base case. The costs of the CCS type of power generation technologies used in this study are based on IEA-OECD (2004), while the costs for other power generation technologies are based on IEA (2001, 2005a, 2005b) and IAEA (2001). Likewise, the costs of hybrid vehicles are based on Lipman and Delucchi (2003). No greenhouse gas (GHG) mitigation policy intervention is considered in the base case.

The maximum availability of domestic fossil-fuel resources (coal, oil and natural gas) and renewable energy resources during 2005–2050 under the base case is based on DEDE (2006a, 2006b). Both exports and imports of the fossil fuel resources and electricity are considered in the model and there is no limit imposed on imports of the fossil-fuel resources. The export and import energy prices are taken from DEDE (2006a, 2006b).

According to the first revised Power Development Plan (PDP) 2007 (EGAT, 2007), 4000 MW of nuclear based power generation was planned to be introduced from 2020 and this study took this into account. However, we find that the plan has been modified recently and the nuclear power generation capacity has been proposed to be reduced to 2000 MW (EGAT, 2009). In EGAT (2007), the Electricity Generation Authority of Thailand (EGAT) has proposed nuclear fuel as an option to replace old fossil fuel fired power plants on their retirement. Thus, in the present study, the nuclear power generation technology option is included from 2020 onwards. The maximum exploitable level of agricultural