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Effects of carbon tax on greenhouse gas mitigation in Thailand

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This study analyses energy system development and the associated greenhouse gas emissions in Thailand under a reference case and three different carbon tax scenarios during 2013–2050 using a bottom-up cost-minimizing energy system model based on the Asia–Pacific Integrated Assessment Model (AIM/Enduse) framework. It considers the role of the renewable energy technologies as well as some emerging GHG-mitigating technologies, e.g. carbon capture and storage (CCS) in power generation, and GHG reduction in the country, and found that the power sector will play a major role in CO_2 emission reduction. Under the carbon tax scenarios, most of the CO_2 emission reduction (over 70%) will come from the power sector. The results also indicate the very significant potential for CO_2 emission reduction through a significant change in the transport system of the country by shifting from low-occupancy personal modes of transport to electrified MRTS and railways.

Keywords: carbon pricing; CO_2 reductions; energy systems; low-carbon society; policy instruments; scenario modelling; Thailand

Cette étude analyse le développement du système énergétique et les émissions de gaz à effet de serre associées en Thaïlande selon un cas de référence et trois différents scénarios de taxe carbone pendant la période 2013–2050 au moyen d'un modèle ascendant de minimisation du coût du système énergétique sur la base du cadre du modèle d'évaluation intégrée de l'Asie pacifique (AIM/Enduse). L'étude prend en compte le rôle des technologies d'énergie renouvelable ainsi que certaines technologies émergentes de réduction des GES, telles que la capture et le stockage du carbone (CSC) dans la production d'énergie et la réduction de GES dans le pays et révèle que le secteur de l'énergie jouera un rôle majeur dans la réduction des émissions du CO_2. Selon les scenarios de taxe carbone, la plupart des réductions d'émission de CO_2 (plus de 70%) viendront du secteur de l'énergie. Les résultats indiquent aussi un potentiel de réduction des émissions de CO_2 très caractéristique dans le système national du transport par le passage d'un mode de transport individuel à faible occupation au MRT et au ferroviaire.

Mots clés: fixation du prix du carbone; instruments de politique; modélisation de scenarios; réductions de CO_2; société sobre en carbone; systèmes énergétiques; Thaïlande

1. Introduction

Thailand is the second largest economy among the countries in the Association of South East Asian Nations (ASEAN) (IMF, 2008). The country is also the second-largest emitter of CO_2 in the ASEAN region. The CO_2 intensity of the country in 2004 was nearly 2.2 times that of the OECD as a whole. 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. In the face of global warming and growing international efforts to reduce greenhouse gas (GHG) emissions, it is

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important to identify the major options for GHG emission mitigation and their potential not only in industrialized countries but also in fast-growing developing countries such as Thailand.

Thailand is heavily dependent on imported energy in that it accounts for about 49% of the total primary energy supply in the country. Thus it is also of interest to analyse the effects of GHG reduction policy options on the development of a low-carbon economy and the energy security of the country over the longer term.

There have been several studies on energy system development and GHG emissions in Thailand (see, e.g., Shrestha et al., 1998, 2007; NEPO, 1999; Tanatvanit et al., 2003, 2004; Limmeechokchai and Suksuntornsiri, 2007a, 2007b). However, these studies do not examine the implications of carbon tax. Santisirisomboon et al. (2001) have analysed the effects of a carbon tax in the power generation sector of Thailand, while Malla and Shrestha (2005) analysed the effects of carbon tax on the Thai economy using a general equilibrium framework for the period 2000–2030. However, neither of these studies considered the effects of a carbon tax on disaggregated energy technology options for GHG reduction on the national energy system as a whole. Furthermore, these studies did not have a planning horizon covering the period up to 2050.

In the present study, we examine the prospects for CO_2 reduction from the Thai economy during 2013–2050 under three different carbon tax scenarios using a bottom-up energy system optimization model. The model includes different energy resource and technology options to meet the demand for energy services during the planning horizon of 2000–2050. In order to provide a broad range of options for GHG mitigation in the country, the model includes emerging technology options such as carbon capture and storage (CCS) along with clean coal technologies (such as IGCC, PFBC), fuel cells and hybrid vehicles, as well as conventional technology options in different sectors. It also includes biofuels as an energy resource option in the transport sector and the nuclear technology option for power generation.

Given the present heavy dependence of the country on low-occupancy vehicles as a means of passenger transport,[1] an analysis was also carried out to assess the effects of a partial shifting of the passenger transport demand from low-occupancy vehicles to the electrified mass rapid transport (MRT) system and railway services. This provides an insight into the level of GHG emission reduction that could be achieved through such policies in addition to the level of reduction achievable through a carbon tax in the absence of such modal shifts.

Section 2 describes the methodology used in the study; Section 3 provides scenario descriptions; the base case analysis is presented in Section 4, followed by analyses of the effects of carbon taxes in Section 5. The final section presents key conclusions and final remarks as well as the policy implications of the study.

2. Methodological approach

The study uses a bottom-up energy system model developed for Thailand using the Asia–Pacific Integrated Assessment Model (AIM)/Enduse framework (Kainuma et al., 2003). The model is broadly classified into two main components: (i) energy supply and conversion and (ii) service demand. The energy supply and conversion component represents energy extraction, imports and conversion of primary energy to secondary energy. In this component, coal mining, natural gas extraction, refining of crude oil, and power generation are considered. For power generation, 28 existing and new technology options are considered. Among the new technology options considered, seven are coal- and natural-gas-based carbon capture and storage (CCS) technologies. We have also considered nuclear as a potential power generation technology of the future.

The Thai economy is divided into five main sectors: agriculture, commercial, industrial, residential and transport. The industry sector has been subdivided into cement, steel, sugar, paper, chemicals, food, equipment, textiles and others. Similarly, transportation is sub-divided into passenger and freight transport. 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 292 existing and candidate technology options are considered in the study 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 population growth. Thailand's GDP projection during 2000–2016 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. It is assumed that service demand in a given year is linearly proportional to the value added in the year.

The model is based on linear programming and comprises an objective function to minimize total energy system cost year by year, subject to a number of constraints including those on service demand, energy resource availability, existing device stock, maximum allowable quantity of devices and emissions (see Kainuma et al., 2003 and NIES, 2007). The total cost comprises annualized fixed cost of recruited devices during a year, variable operating costs (i.e. operation and maintenance costs of devices, and fuel costs), cost of installing removal devices (e.g. flue gas desulfurizers for pulverized coal-fired power plants) and taxes.

3. Scenario descriptions

The base case scenario is defined as the business-as-usual case, i.e. the continuation of current economic, demographic and energy sector trends and policies, without any mitigation policy. The maximum availability of domestic fossil fuel resources (coal, oil and natural gas) during 2000–2050 under the base case is given in Table 1. However, no limit is imposed on imports of these fossil fuel resources.

TABLE 1 Energy resources reserve of Thailand (as of December 2005)

Type	Proven reserves	Probable reserves	Possible reserves	Total
Crude oil (million bbl)	192	119	76	387
Condensate (million bbl)	261	293	158	712
Natural gas (bcf)	10,743	11,598	9,555	31,896
Lignite (million tons)				2,870
Domestic hydro potential (MW)				15,112

Source: DEDE (2006a).

According to the latest Power Development Plan (PDP) (EGAT, 2007), 4,000 MW will be provided by nuclear, which is introduced from 2020. Thus the nuclear power generation option is also included in the study from 2020 onwards. The Thai Ministry of Energy has estimated a minimal amount of renewable energy resource potential for power generation at present in the country (Greacen and Bijoor, 2007). Thus the maximum exploitable level of solar and wind for power generation is assumed to be 5,000 MW and 1,100 MW, respectively, in this study. Likewise, the maximum exploitable level of agricultural residues (sugar cane residues – i.e. bagasse and tops and leaves, paddy husks, corncobs and others) is assumed to be 14,112 ktoe (Santisirisomboon et al., 2001; DEDE, 2006b; Prasertsan and Sajjakulnukit, 2006). The maximum level of plantation-based biomass is assumed to be 7,500 ktoe (Sajjakulnukit and Verapong, 2003; Santisirisomboon et al., 2001). It is assumed that the plantation-based biomass is produced on a sustainable basis and therefore there would be no net CO_2 emission involved. No carbon tax is considered in the base case scenario. The planning horizon of the study is 2000–2050 (50 years) with 2000 as the base year. A 10% discount rate (ADB, 1998) is used in the study.[2] All costs are expressed at the constant prices of the year 1995.

Three carbon tax scenarios are considered in the study.[3] They are:

- The use of a carbon tax of US\$10/tCO_2 starting from 2013, which will exponentially rise to US\$100/tCO_2 by 2050, all other things remaining the same as in the base case (hereafter called the 'C10+ scenario')
- The use of a carbon tax at a constant rate of US\$75/tCO_2 from 2013 to 2050, all other things remaining the same as in the base case (hereafter, 'C75 scenario').
- The use of a carbon tax at a constant rate of US\$100/tCO_2 from 2013 to 2050, all other things remaining the same as in the base case (hereafter, 'C100 scenario').

The carbon tax profiles in the three scenarios are shown in Figure 1.

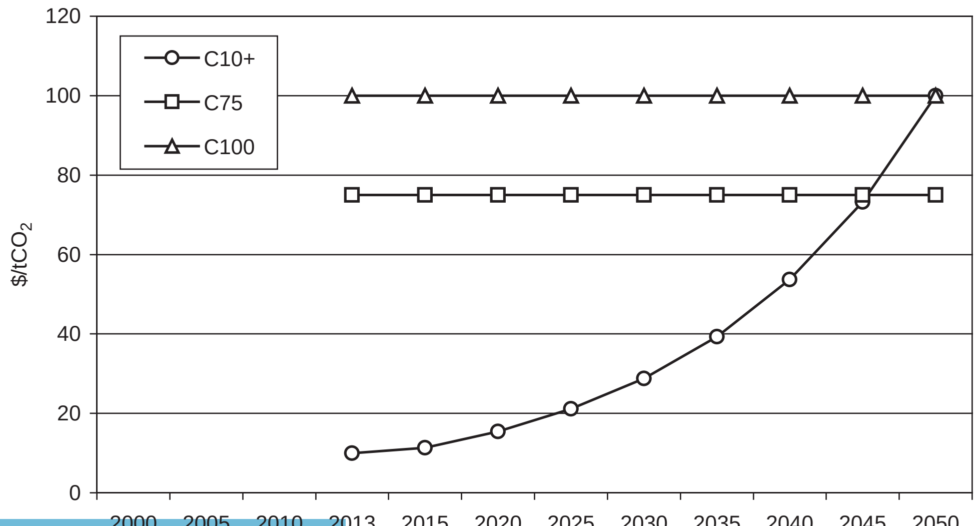

FIGURE 1 Three alternative carbon tax cases, \$/tCO_2.

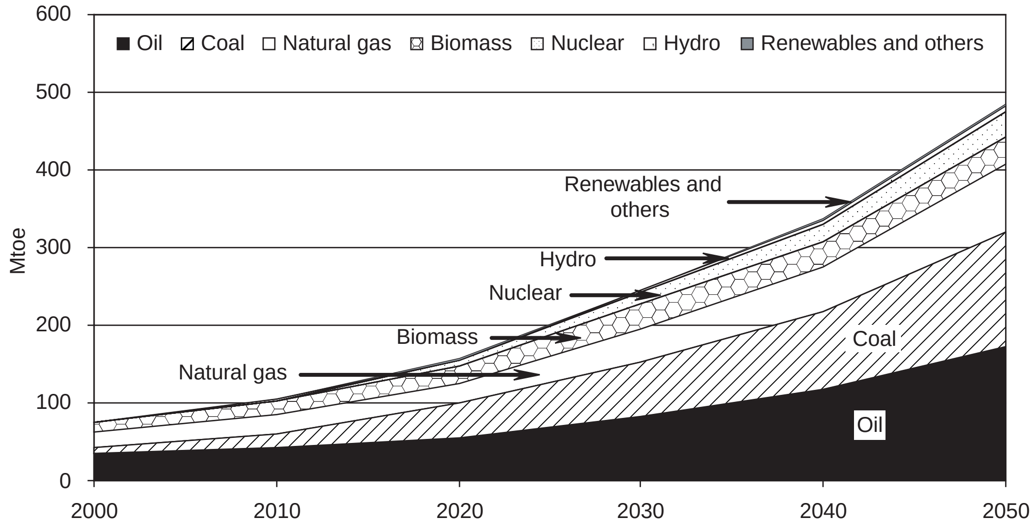

FIGURE 2 Total primary energy supply, Mtoe.

4. Base case analysis

4.1. Total primary energy supply (TPES) and energy mix

The total primary energy supply (TPES) increases with an annual average growth rate (AAGR) of 4.1% during 2000–2050. As a result, the TPES is found to increase from 75 Mtoe in 2000 to 484 Mtoe by 2050 (Figure 2). The combined share of oil and natural gas decreases from 71% in 2000 to 54% by 2050, while the share of coal (mainly imported) increases from 11% to 30% during the period. The use of nuclear power generation technology starts in 2020 and would acquire a share of 7% in TPES in 2050. The available biomass energy resource would be almost fully used from 2030 onwards; as a result, its share would decrease from 17% in 2000 to 7% in 2050. The share of hydroelectricity (including imported hydroelectricity) remains at about 1% throughout the period. Similarly, renewable energy (biogas, geothermal, solar and wind) and other sources (municipal solid waste) would have a very small share in TPES (less than 1%) during the study period. The results show that the share of imported energy (including imported coal, crude oil, natural gas, hydro and nuclear) will increase from 49% in 2000 to 74% by 2050.

4.2. Sectoral energy consumption

The total energy consumption (TEC) of different sectors is estimated to grow more than sixfold (i.e. from 47 Mtoe in 2000 to 376 Mtoe in 2050). The transport and industrial sectors dominate total energy consumption (see Table 2). Together these sectors accounted for 74% of TEC in 2000, and their share would grow to 84% by 2050. The share of industrial sector energy consumption grows till 2030 and decreases thereafter (Figure 3). The commercial sector energy consumption share would rise significantly, while the shares of the agriculture and residential sectors in TEC decline sharply during the planning horizon.

4.3. CO_2 emission

CO_2 emission is found to grow nearly sevenfold in the base case, i.e. from 158 million tonnes in 2000 to 1,262 million tonnes by 2050 (see Figure 4). Total cumulative CO_2 emission during the

TABLE 2 Share of sectoral energy consumption during 2000–2050 under base case, %

Sector	Year 2000	Year 2050
Transport	39	41
Industrial	35	43
Commercial	6	11
Residential	16	4
Agricultural	4	1
Total	100	100

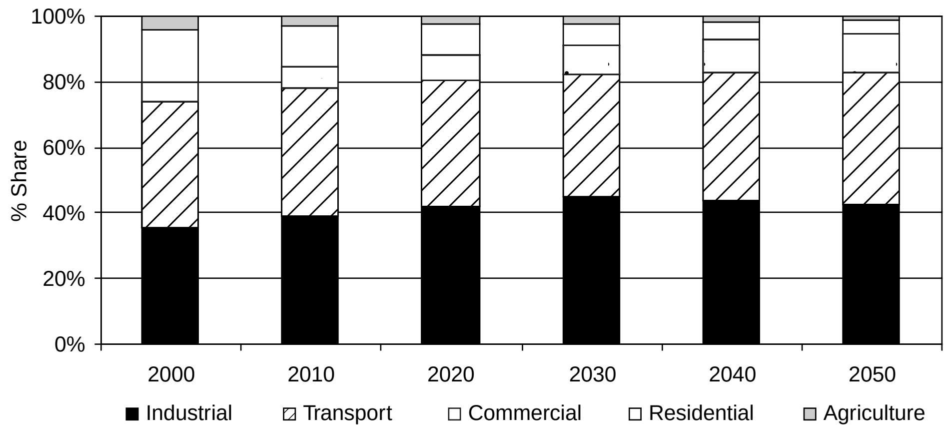

FIGURE 3 Yearly share of sectoral energy consumption during 2000–2050 under the base case, %.

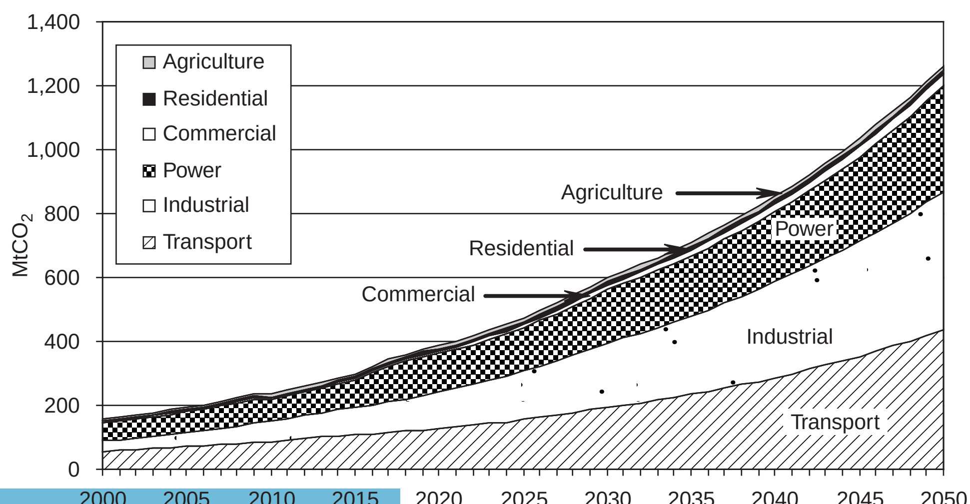

FIGURE 4 Sectoral CO_2 emission under base case, $MtCO_2$.

planning horizon is estimated to be 28,129 MtCO_2. The transport sector accounts for the highest share (34%) in cumulative CO_2 emission, followed by the industrial (33%) and power sectors (28%). Together, the transport, industry and power sectors had a share of over 93% of total CO_2 emission in 2000 and this would increase to 95% in 2050. The share of the power sector in CO_2 emission is found to decrease from 37% in 2000 to 26% in 2050. This is mainly because of penetration of nuclear energy technology and biomass-based power generation from 2020 onwards. The residential, agriculture and commercial sectors together have a relatively small share in CO_2 emission, which would decrease from 7% in 2000 to 5% by 2050.

5. Effects of carbon tax

The effects of three different levels of carbon tax (C10+, C75 and C100) on TPES, sectoral energy mix and CO_2 emission are discussed in the following sections.

5.1. Primary energy supply and fuel mix

The introduction of a carbon tax does not have a significant effect on the TPES. With the carbon tax, the TPES would increase from 75 Mtoe in 2000 to 471 Mtoe by 2050 under all the carbon tax scenarios. As a result of carbon tax, the share of natural gas is found to increase by 0%, 6% and 7% in scenarios C10+, C75 and C100, respectively, as compared with that in the base case, while the share of coal is found to decrease by 2%, 7% and 8% in the C10+, C75 and C100 scenarios, respectively, during 2000–2050. The share of natural gas in annual TPES is found to decrease until 2041 and would increase thereafter in C10+. In C75 and C100, the share of natural gas would decline until 2012, increase during 2013–2026, and would then decline again until 2050. The annual share of coal is found to increase gradually during the planning horizon (see Figure 5). The share of oil in cumulative TPES during the planning horizon would not change significantly, although the annual share of oil would decrease by 2022–2024 and would increase thereafter in all carbon tax scenarios. Thus, the carbon tax would have a major effect on the use of coal and natural gas, while its effect on oil would be negligible during 2000–2050.

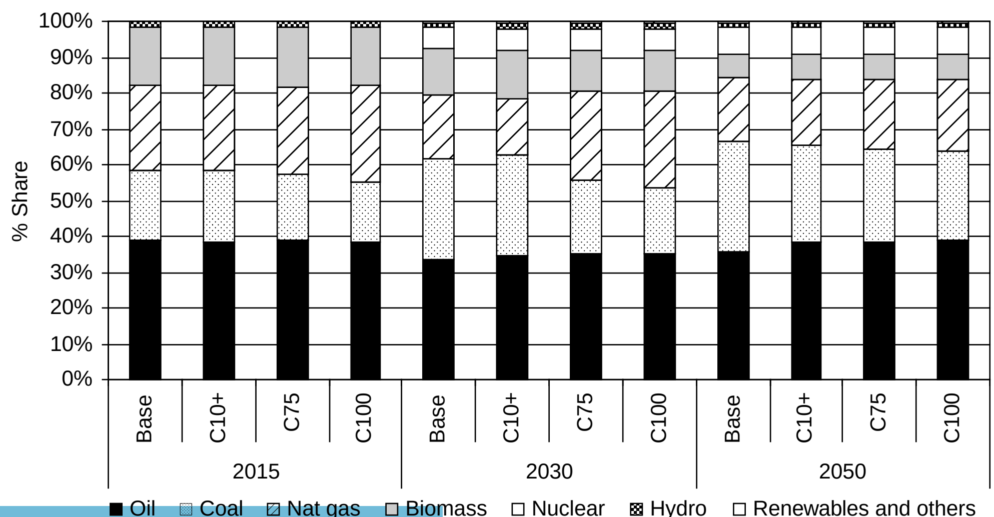

FIGURE 5 Fuel share in total primary energy supply in carbon tax scenarios, %.

5.2. Sectoral energy mix

The power, industrial and transport sectors are found to experience major changes in terms of the energy mix as a result of carbon tax. In the power sector, coal use would decrease while natural gas would increase significantly (Table 3). The nuclear generation share would not change during the planning horizon. The share of hydropower, biomass and other renewables would increase slightly with a carbon tax, while that of other renewables would have a small increment.

In the industrial sector, the share of coal in the cumulative energy consumption of the sector is found to decrease during the planning horizon with carbon tax (Table 4). The share of natural gas in the cumulative energy consumption of the sector during the planning horizon is found to increase over time. There would be no significant change in the shares of biomass, petroleum products and electricity.

In the transport sector, the shares of gasohol (90% gasoline) and biodiesel (90% diesel) vehicles in transport sector energy consumption would increase from nearly 5% in the base case to over

TABLE 3 Effect of carbon tax on energy mix of cumulative power generation during 2000–2050

Energy type	Percentage share in total energy used in the power sector			
	Base case	C10+	C75	C100
Coal	51	44	28	27
Natural gas	15	20	36	36
Biomass	7	8	8	8
Oil	0	0	0	0
Nuclear	15	15	15	15
Hydro	11	11	11	12
Other renewables	1	2	2	2

TABLE 4 Effect of carbon tax on energy mix (in cumulative energy consumption) of the industrial sector during 2000–2050

Energy type	Percentage share in total energy used in the industrial sector			
	Base	C10+	C75	C100
Biomass	8	7	7	7
Coal	41	40	36	34
Electricity	16	16	16	16
Natural gas	19	21	24	26
Petroleum products	9	9	9	9
Heat	7	7	7	7

TABLE 5 Effect of carbon tax on energy mix (in cumulative energy consumption) of the transport sector during 2000–2050

Type	Percentage share in total energy used in the transport sector			
	Base	C10+	C75	C100
Gasoline	49.7	21.6	22.7	22.8
Gasohol	1.4	13.8	13.9	13.9
Diesel	35.9	20.6	20.8	20.8
Biodiesel	3.4	38.7	39.0	39.0
Natural gas	7.9	3.7	2.1	2.0
LPG	1.4	1.3	1.2	1.2
Electric	0.1	0.1	0.1	0.1
Fuel cell	0.2	0.2	0.2	0.2

50% in all carbon tax scenarios during the planning horizon. On the other hand, the shares of pure gasoline and diesel vehicles in the sectoral energy consumption would fall under carbon tax scenarios. Because efficient gasohol and hybrid biodiesel vehicles are significantly more energy-efficient than natural gas vehicles, the shares of natural gas vehicles in the sector's energy consumption are found to fall under the carbon tax scenarios, while the shares of LPG, electric and fuel-cell vehicles are almost entirely unaffected (Table 5) .

5.3. CO_2 emission reduction

The CO_2 emissions over the planning period in the base case and the carbon tax cases are shown in Figure 6. Among the carbon tax scenarios, C100 results in the highest CO_2 emission reduction

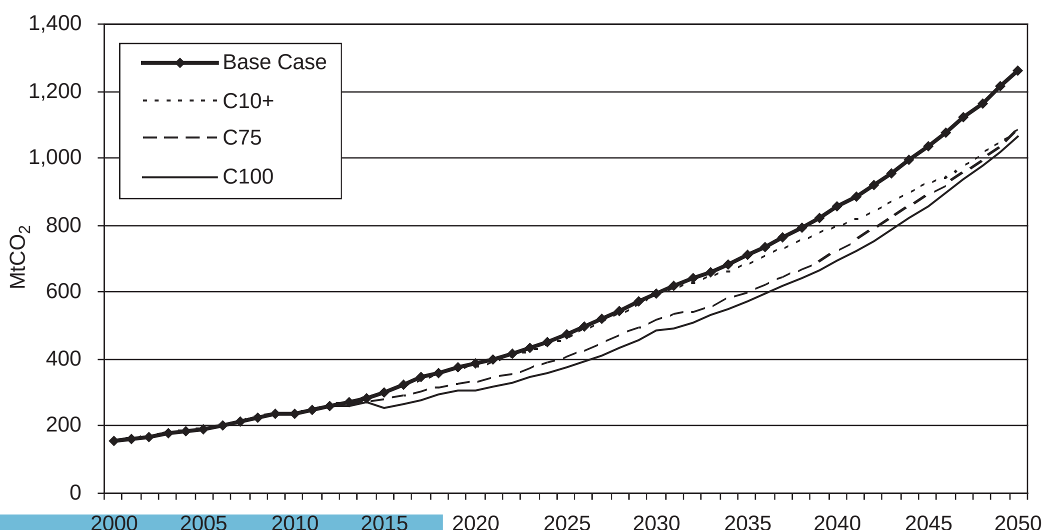

FIGURE 6 Yearly CO_2 emission under base case and different carbon tax scenarios, $MtCO_2$.

TABLE 6 CO_2 emission reduction in carbon tax scenarios

Sectors	Base case cumulative CO_2 emission, $MtCO_2$	Cumulative emission reduction from the base case emission level under carbon tax scenarios, $MtCO_2$		
		C10+	C75	C100
Agriculture	549	0	0	0
Commercial	712	0	0	0
Industrial	9,189	157	467	579
Residential	405	0	(8)	(6)
Transport	9,532	354	433	445
Power	7,743	1,179	2,810	3,607
Total	28,130	1,691	3,711	4,632

Note: The figure in parentheses denotes an increase in CO_2 emissions from the base case.

(16.5%) followed by C75 (13.2%) and C10+ (6.0%) (see Table 6). With carbon tax, the total system cost is found to increase by 6%, 16% and 20% in the C10+, C75 and C100 cases, respectively, during 2000–2050 as compared with that in the base case.

As a result of the carbon tax, the highest CO_2 emission reduction would take place in the power sector, followed by the transport and industrial sectors (see Table 6). The power sector accounts for 70% of total CO_2 emission reduction in the C10+ scenario, 76% in the C75 scenario and 78% in the C100 scenario. It should be noted here that, with the introduction of a carbon tax, reduction in CO_2 emission is mainly achieved through the use of coal-based carbon capture and storage (CCS) and natural-gas-based advanced combined cycle power generation.

In C10+, the share of the transport sector in CO_2 emission reduction is higher (21%) than that of the industrial sector (9%), while the opposite is the case in the C75 and C100 scenarios. The effect of carbon tax on CO_2 emission reduction in other sectors is not found to be significant.

In the agriculture sector, efficient electric motors and efficient diesel tractors were the only two types of efficient energy technology options considered in our model. Both these technologies would be selected in the base case to their maximum limit allowed. Thus, their usage would not be affected by carbon tax and, as a result, there is no reduction in CO_2 emission in this sector.

In the commercial sector, efficient air conditioners and compact fluorescent lamps (CFLs) were the efficient options considered for cooling and lighting service demands along with their conventional counterparts. It was found that CFLs would be selected to their maximum extent in the base case; thus carbon tax would not affect them. As for the efficient air conditioning devices, they would become cost-effective with carbon tax and would substitute for conventional air conditioning devices in the carbon tax cases. Although this reduces electricity consumption from the sector due to carbon tax, CO_2 emission reduction associated with the reduced electricity consumption is accounted for (included) under the power sector. Thus, there appears to be no reduction in CO_2 emission with the introduction of a carbon tax in the commercial sector.

In the residential sector, efficient lamps (fluorescent tubes and CFLs) would be selected to the maximum level in the base case; thus there is no change in their shares with the introduction of a carbon tax. In the case of space cooling service demands, as in the commercial sector, conventional air conditioners are substituted by efficient air conditioners under carbon tax cases; but the

CO_2 reduction associated with reduced electricity use by the efficient air conditioners is accounted for in the power sector CO_2 emission.

In residential cooking, electric stoves are partially replaced by efficient LPG stoves with the introduction of a carbon tax. With the increased use of LPG in the carbon tax cases, some increase in CO_2 emission would appear in the residential sector under the C75 and C100 scenarios (see Table 6). This is mainly because CO_2 emissions associated with electric stoves are reflected in the power sector emission rather than in the residential sector emission (see Table 6).

5.3.1. Role of renewable energy technologies in CO_2 emission reduction

In the base case, the share of renewable energy (including hydropower and biomass) in TPES is expected to decrease from 18% in year 2000 to 9% in year 2050. This is because biomass, hydropower and geothermal energy resources would be utilized to their maximum exploitable limit considered in the study after 2030 in the base case. In the power sector, the share of renewable energy in TPES would be 19% (including imported electricity and biomass) in the base case. The share would slightly increase to about 21% under carbon tax scenarios.

The use of solar photovoltaic (PV) technology in electricity generation has not been an attractive option in the base case, where the cost of solar PV is assumed to be fixed at US$4,240/kW (constant 1995 price) throughout the study period. However, the cost of solar technology is expected to fall over time due to the learning-by-doing effect (EPIA, 2006). IEA (2004) has used a learning rate of 18% for solar PV technology while analysing the competitiveness of CCS technology. Therefore, in this study we examined the effect of an 18% learning rate (LR) along with carbon tax. The results show that the learning-by-doing effect on solar technology would have significant effects on its adoption and CO_2 emission reduction in the power sector (Table 7).

5.3.2. Role of emerging energy technologies in CO_2 emission reduction

As discussed in Section 5.3, the carbon tax would have the largest effect on the power sector in terms of CO_2 emission reduction. One of the reasons for this is the adoption of a significant level of CCS-based power generation technologies under the carbon tax scenarios unlike in the base case, in which only a low level of CCS technology was cost-effective. The study shows that in the carbon tax scenarios, the share of electricity production based on CCS power generation technologies would increase to 7%, 14% and 23% in the C10+, C75 and C100 scenarios, respectively. Similarly the total power generation from natural gas power plants based on advanced combined cycle technology would increase from 14% in the base case to 19%, 35% and 31% in the C10+, C75 and C100 scenarios, respectively. Power generation from coal-fired IGCC and PFBC plants

TABLE 7 Effects of learning by doing on solar PV technology adoption and CO_2 emission reduction

	Base case	Carbon tax scenario (with 18% learning rate)		
		CT10+	CT75	CT100
Cumulative solar power generation, Mtoe	0	19	20	20
Power sector cumulative emission, $MtCO_2$	7,743	6,426	4,857	4,025
Emission reduction, $MtCO_2$	–	1,317	2,886	3,718
Year of penetration	–	2025	2013	2013

TABLE 8 Effects of increments in the CCS-based power plant costs on power generation and CO_2 emission from the power sector

	Base case	C10+		C75		C100	
		At reference price of CCS	At 25% higher price of CCS	At reference price of CCS	At 25% higher price of CCS	At reference price of CCS	At 25% higher price of CCS
Total power generation based on CCS technology, Mtoe	0	92	58	189	113	314	276
Total power generation based on combined cycle technology, Mtoe	199	266	275	483	532	434	472
Total CO_2 emission in the power sector, $MtCO_2$	7,742	6,563	6,737	4,932	5,247	4,135	4,248

would decrease from 26% in the base case to 19%, 1% and <1% in the C10+, C75 and C100 scenarios, respectively. Power generation from biomass-based IGCC plants would increase from about 2% in the base case to about 4% in the carbon tax scenarios.

The costs of the CCS type of power generation technologies used in this study are based on IEA (2004), while the costs for other power generation technologies are based on IEA (2001, 2005a, 2005b) and IAEA (2001). It should be noted that, being an emerging technology, the cost of CCS involves some uncertainties. Therefore we also examined the effect of a 25% increase in the capacity cost of CCS devices retrofitted to existing plants on CO_2 emission and level of CCS-based power generation under the carbon tax scenarios. As shown in Table 8, at the 25% higher cost of CCS capacity, the level of CCS-based power generation would be reduced, while power generation based on combined cycle power plants would increase. As a result, the power sector CO_2 emission would increase somewhat at the increased CCS capacity cost.

5.3.3. Effect of modal shift in passenger transport on CO_2 emission reduction

In Thailand, buses, cars, vans and pickups[4] are the most popular modes of passenger travel, along with motorcycles (OCLMT, 2000). In recent years the Bangkok Sky Train Service (BTS) and Mass Rapid Transit System (MRTS) have also been introduced, to a limited extent, for passenger transport services in the Bangkok metropolitan area (BTS, 2007; MRTA, 2007). It would therefore be of interest to investigate the effects on CO_2 emission in Thailand of shifting part of the passenger transport demand from low-occupancy passenger transport services (cars, vans and pickups) to MRTS and railway services from 2015 to 2050. For such an analysis, it is assumed that 10% of the passenger travel demand of cars, vans and pickups would be shifted to MRTS and railway services by the year 2015, while the shift would increase to 20% in 2030 and to 30% by the year 2050.[5] The results show that the modal shift in passenger transport would result in significant CO_2 emission reductions under the carbon tax scenarios (i.e. a reduction of 7.9% under C10+, 15.0% under C75, and 18.5% under C100) (see Table 9).

TABLE 9 Effects of modal shift in passenger transport on CO_2 emission reduction

Cumulative CO_2 emission in $MtCO_2$ during 2000–2050	Base	C10+	C75	C100
CO_2 emission without modal shift	28,130	26,439	24,419	23,498
CO_2 emission with modal shift		25,896	23,902	22,925
Total emission reduction		2,234	4,228	5,205

TABLE 10 Total NO_x and SO_2 emission reduction in carbon tax scenarios during 2000–2050

Sector	Base case NO_x emission Mtons	NO_x emission reduction, Mtons			Base case SO_2 emission Mt	SO_2 emission reduction, Mt		
		C10+	C75	C100		C10+	C75	C100
Industrial	27.8	0.7	1.9	2.5	65.8	9.0	18.9	17.7
Power	26.4	3.6	9.2	11.3	123.5	6.8	64.7	82.5
Transport	90.9	0.0	0.0	0.0	36.2	1.8	1.9	2.0
Others	10.0	0.0	0.1	0.0	5.6	0.0	0.1	0.0
Total	155.1	4.3	11.2	13.8	231.1	17.6	85.6	102.2

5.4. Co-benefits of carbon tax

Table 10 presents the effects of a carbon tax on SO_2 and NO_x emissions. The NO_x emission reduction would be the highest in the power sector, followed by the industrial sector (see Table 10). Similarly, the power sector accounts for the highest level of SO_2 emission reduction and is followed by the industrial and transport sectors. It should be noted that the reductions in SO_2 and NO_x emissions would be even larger if the aforementioned modal shift from low-occupancy vehicles to MRTs and railways is also considered.

6. Conclusions

This study shows that there would be almost a sevenfold increase in CO_2 emission in the base case during the planning horizon. Three sectors – i.e. transport, industry and power – together account for over 93% of the total CO_2 emission in 2000 and 95% by 2050.

With the introduction of a carbon tax, there would be a shift in energy mix from coal to natural gas in the power and industrial sectors. In the transport sector, the share of gasohol (90% gasoline) and biodiesel (90% diesel) use in vehicles would significantly increase, whereas the share of gasoline and diesel use in vehicles would decrease.

Under the C10+ scenario, the cumulative CO_2 emission reduction would be 6.0% during the planning horizon as compared with the base case emission. The corresponding figures under the C75 and C100 scenarios are 13.2% and 16.5%, respectively. If a modal shift of passenger transport from low-occupancy vehicles to MRTS and railways (from 10% in 2015 to 30% in 2050) was realized, the reduction in CO_2 emission would increase from 6.0% to 7.9 % in the C10+ case, from 13.2% to 15.0% in the C75 case, and from 16.5% to 18.5% in the C100 case.

The study also shows that the power sector will play a major role in CO_2 emission reduction. Most of the CO_2 emission reduction (over 70%) will come from the power sector under the carbon tax scenarios. This is mainly due to the adoption of CCS technologies as well as nuclear power generation technology. A sensitivity analysis with a 25% increase in the CCS capacity cost was found to marginally increase CO_2 emission from the power sector. Furthermore, the analysis reveals that biomass and other renewable energy technologies would not play a significant role in Thailand in CO_2 reduction under these carbon tax scenarios.

Thailand depends largely on imported energy sources and this dependence is expected to increase further in future. The imposition of a carbon tax does not seem to have any appreciable effect in reducing the energy import dependency of the country, due to its relatively small renewable energy resource potential. The results of the study also show that if Thailand is to pursue a development path towards a low-carbon society, CCS and nuclear technologies are the major options to be adopted for power generation in the country. Given the heavy reliance on low-occupancy personal vehicles for passenger transport, the results of the present study also show a very significant potential for CO_2 emission reduction through a significant change in the transport system of the country by shifting to electrified MRTS and railways from low-occupancy personal transport modes.

It should be noted that in the present study we have used a bottom-up partial equilibrium type of energy system model. As a result, the effects of a carbon tax on the demand for different types of energy have not been captured in our analysis. With the increase in the relative price of carbon-intensive fuels, the demand for services based on such fuels is expected to fall, which in turn would reduce the demand for such fuels. If such effects are considered in the model, a further reduction in CO_2 emission below the levels suggested by the present study is likely.

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Notes

1. See OCLMT (2000).
2. The Asian Development Bank (ADB, 1998) states, citing the National Economic and Social Development Board (NESDB) of Thailand, that the Government of Thailand uses a 10% discount rate.
3. In the carbon tax and climate stabilization literature, studies have considered various carbon tax rates varying from US$10/tC to US$600/tC, with different intertemporal profiles (e.g. Edmonds et al., 2004; Smekens-Ramirez Morales, 2004; Vuuren et al., 2004). The three tax scenarios are well within the range of tax rates considered in the literature and also provide some variations in the tax profiles over time.
4. Vans and pickups are light-duty passenger vehicles having a carrying capacity of 12–16 people.
5. The passenger transport system in Thailand at present is predominantly road-based, with less than a 3% share for railways and MRTS. The government, in its policy document, has recently stated the goals of increasing the shares of railways and MRTS without giving any explicit targets. We have therefore considered these figures as a scenario for modal shift. Given that MRTS and railways already account for over 25% of the passenger transport services in some countries (e.g. Japan), the figures considered here as a scenario during 2015–2050 in the face of growing oil prices and climate change concern should not be considered unrealistic.

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