ENERGY SYSTEM DEVELOPMENT AND ENVIRONMENTAL IMPLICATIONS UNDER CO_2 EMISSION REDUCTION TARGETS IN A DEVELOPING COUNTRY

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Overview

Developing countries are not legally required by the Kyoto Protocol (KP) of the United Nations Framework Convention on Climate Change (UNFCCC) to reduce greenhouse gas (GHG) emissions. However, the first commitment period of the KP runs only up to 2012 and the global community has already begun discussing the future climate regime beyond 2012 (i.e., post-Kyoto) that involves active participation from developing countries (DCs). In anticipation of growing national and international concerns for mitigation of GHG emissions and increasing pressure on DCs to participate in the post-Kyoto climate regime, it is important to identify sustainable energy pathways that lead to low carbon economy in DCs in the future. This requires identification of various options for mainstreaming climate concerns developmental policies and strategies of individual DCs. Thus, it is of interest for policy makers to analyze the implications of post-Kyoto CO_2 emissions reduction (ER) targets on energy and environment in DCs.

This study examines energy system development and its associated greenhouse gas and local air pollutant emissions under base case and three different emissions reduction (ER) targets in Thailand during 2000-2035.

Methods

To analyze these issues in detail, an energy system optimization model for Thailand is developed in the framework of AIM/Enduse model – a model of the Asia-Pacific Integrated Assessment Model (AIM) family. The methodology used is essentially an end-use approach that interrelate the energy service demand with the population, gross domestic product (GDP), energy price and technological change.

The AIM/Enduse model of Thailand 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 is considered.

Results

Energy implications

Increasing use of fossil fuels and dominant shares of transport and industry sectors in total energy systems of the country characterizes the base case, i.e., without any policy interventions. The study shows that in this scenario, the total primary energy supply (TPES) would increase by more than three-folds from 77 Mtoe in 2000 to 285 Mtoe in 2035 and the share of fossil fuels (coal, oil and natural gas) in TPES would increase from 81% in 2000 to 87% in 2035. Likewise, the total final energy demand (FED) would increase from 49 Mtoe in 2000 to 215 Mtoe in 2035, an increase of more than four-folds. The country's energy import dependency (EID) – defined as net energy import as a percentage of TPES – would increase from 50% in 2000 to 77% in 2035 showing increasing vulnerability to energy supply uncertainties related to external sources.

With ER targets set from 2013, the results indicate substantial changes in the primary fuel-mix during 2013-2035. Coal share in TPES would fall during the period: It would reduce by 6% under ER5 (i.e., reduction of 5% of the base case emissions during 2013-2035) and by 12% under ER10 and ER15 cases as compared to the base case. On the other hand, natural gas share in TPES would increase steadily by 2%, 7% and 10% under ER5, ER10 and ER15 cases respectively. While no biofuels is used in road transportation in the past, its share in TPES for transportation would reach 6% (3.3 Mtoe) under ER15 by 2035. However, the study shows that new and renewable energy (NRE) sources would play a limited role in primary energy-mix under ER targets.

CO_2 and local air pollutant emissions

Country's energy related CO_2 emissions would increase at an AAGR of 4.1%, i.e., from 158 Mt in 2000 to 676 Mt in 2035. Power-, industry- and transport- sector together would contribute about 93% of total CO_2 emissions during 2000-2035. In terms of the CO_2 emission by fuel type, coal-, oil- and natural gas- use accounted for 22%, 55% and 23% of the total CO2 emissions respectively in 2000, while coal use would account for the most (i.e., 43%) by 2035, followed by oil (40%) and natural gas (17%). Likewise, the results of the study find that local air pollutant emissions would also increase in the country during the study period. The SO_2 emission would increase by almost five-folds (from 899 kt in 2000 to 5,604 kt by 2035) while the NO_x emission would increase by four-folds (926 kt in 2000 to 3,413 kt in 2035) during 2000-2035.

With ER targets, most of the CO_2 emission reduction would take place in the power, industry and transportation sectors as these sectors would consume more than 90% of TPES in the country. The power sector alone would contribute most of CO_2 emissions reduction varying from 44% under ER5 to as high as 58% under ER15 during 2013-2035. The CO_2 ER targets also result in reducing SO_2 and NO_x emissions as co-benefits. ER targets would be more effective in reducing SO_2 emissions than NO_x emissions.

Effects on changes in energy-mix and technologies for electricity generation

The results indicate that under ER15, electricity generation from coal- and natural gas- plants with carbon capture and storage (CCS) technology would require about 23% of total coal requirements and 5% of total natural gas requirements during 2013-2035. With ER15, the study shows that within NRE sources for electricity generation, the share of new renewables, biomass and hydro would increase by 22% (i.e., 12 Mtoe), 4% (i.e., 8 Mtoe) and 1% (i.e., 0.3 Mtoe) respectively as compared to base case during 2013-2035. In terms of technology mix for electricity generation, the study shows substantial changes under the ER targets. Integrated gasification combined cycle (IGCC) with CCS technology and advanced natural gas combined cycle plants would become economically viable options for electricity generation under ER targets.

Conclusions

Thailand is a heavily fossil fuel intensive economy and is highly dependent on imported energy. Energy security is high on Thai government's agenda. Indeed, more than half of the total primary energy requirement was met through import in 2000 and this study shows that the energy import dependency of the country would reach 77% by 2035. Thailand currently contributes only about 0.7% of the global energy related CO_2 emission. However, if the current trend continues without any mitigation measure, CO2 emission from the country would increase by more than four-folds by 2035 as compared to the 2000 value. The power sector, which is predominantly fossil-fuel based, would contribute the most in total CO_2 emissions, followed by the transport and industry sectors. These three sectors together would contribute more than 93% of the total CO_2 emissions from the country during 2013-2035.

There are significant implications of introducing post-Kyoto CO_2 emissions reduction targets for the structure of energy system as well as CO2 and other local air pollutant emissions. With increasing ER targets, coal share in TPES would fall while natural gas and NRE shares would increase during 2013-2035. However, the fall in coal share in TPES (i.e., 12%) would remain the same under ER10 and ER15 cases due to increasing use of coal based CCS technologies for electricity generation under ER15. The power sector would play a higher role in reducing CO_2 emissions than the other sectors especially at high ER targets varying from 44% under ER5 to as high as 58% under ER15 during 2013-2035. Industry- and transport- sector is the second and the third largest after the power sector accounting for 22% and 20% of total CO_2 emission reduction respectively under ER15 by 2035.

AIM/Enduse model for Thailand is a static year by year optimization model. Thus, results presented in this study could be different from end-use models that consider dynamic optimization over the planning horizon. Furthermore, some of the features of the electricity generation sector such as lumpy nature of investments, discrete nature of power generation capacities and variations in daily load curve are not considered in the selection of power generation plants. Due to data limitations, options of energy from nuclear based technologies in the electricity generation in Thailand are not included in this study. In a subsequent paper, we intend to consider the role of nuclear technologies in the energy system development and the environmental management of Thailand.

References

Please see the conference paper.