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Special Feature on the Kyoto Protocol

Technological Implications of the Clean Development Mechanism for the Power Sector in Three Asian Countries

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This paper analyzes the role of some key technological options (i.e., fuel-switching and renewable energy technologies) available under the Clean Development Mechanism (CDM) for reducing greenhouse gas (GHG) emissions in the power sector of three Asian countries—Sri Lanka, Thailand, and Vietnam. A long-term electricity planning model is used with the aim of minimizing the total net cost of certified emission reduction (CER) benefits from these countries' power sector during 2006 to 2025. The results show that cleaner thermal power generation technologies involving fuel-switching from coal to gas or oil would be the main source of carbon dioxide (CO_2) reduction not only at the presently prevailing CER prices but also at significantly higher prices. The CDM potential of most renewable energy technologies is found to be weak during the study period at prevailing CER prices.

Keywords: Clean Development Mechanism, Renewable energy technologies, Fuel-switching, certified emission reduction (CER) price.

1. Introduction

The Kyoto Protocol has opened up an avenue for mutually beneficial cooperation between developing and industrialized countries through the Clean Development Mechanism (CDM). The prospects of implementing climate-friendly projects under the CDM and getting assistance for sustainable development in that process have raised expectations among policy makers and planners in developing countries. The CDM is expected to be used as an instrument to transfer environmentally sound technologies (ESTs) from industrialized countries (ICs) to developing countries (DCs) for three main reasons. First, the mitigation of greenhouse gases (GHGs) from a CDM project should be additional to that which would occur in the absence of the project. This would require deployment of ESTs instead of conventional technologies. Second, the CDM projects, by definition, have to be implemented in DCs. Third, the CDM is a market-based mechanism and it extends the market for ESTs, whose demand is traditionally limited mainly to ICs, to developing countries. The certified emission reduction (CER) benefits under the CDM improve the financial viability of the ESTs and serve as an incentive for their deployment in DCs. As the viability of ESTs and their adoption in DCs would greatly depend upon their cost and the CER price, questions arise as to what type of ESTs are likely to be adopted at different CER prices and whether the CDM would necessarily result in transfer of new technologies or know-how to DCs.

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As the CDM is a market-based mechanism, a necessary condition is that CDM projects will have to be financially viable at the prevailing CER price. Financial viability alone, however, does not ensure effective implementation of the projects in the presence of legal, institutional/regulatory and other barriers that normally exist in many DCs. Thus, actual potential for adoption of ESTs under the CDM may not be as large as that indicated by the economic potential (i.e., based purely on CER benefits and costs).

Due to the dominant role of the power sector in GHG emissions, this paper first examines the CDM potential and types of cost-effective ESTs involved in the power sectors of three selected Asian countries—Sri Lanka, Thailand, and Vietnam—based on a long-term power generation capacity planning model considering the CER benefits. It also discusses the capital implications of the cost-effective, climate-friendly technological options in the power sectors in the selected countries. Furthermore, some potential barriers to the power sector CDM projects in DCs and measures to overcome them are discussed.

2. The approach

For the purpose of finding out CDM potential, a long-term electricity generation planning optimization model is used. The model determines the optimal technology and fuel options for power generation to meet the projected demand and associated carbon dioxide (CO_2) emissions during the planning horizon (2006–2025). The model is, however, different from a typical electricity planning model in that it determines power generation capacity additions by technology type and fuel requirements that minimize the total discounted cost of electricity production (including costs of capital, fuel, operation, and maintenance) net of total discounted CER revenue that could be earned during the planning horizon. The model also determines the optimal level of CO_2 emissions reduction and corresponding CER revenue at a given CER price (Shrestha and Abeygunawardhana 2004). A number of renewable energy technologies and cleaner fossil fuel-based technology options for power generation are considered in our analysis, while energy efficiency improvement options on the demand side have not been included. Technology options and country-specific maximum available quantities of renewable energy resources considered in the study are presented in table 1, while the unit capital costs of power generation options are shown in table 2. Note that in this paper, the term *renewable energy technologies* (RETs) does not include medium- or large-size hydropower plants, which are treated as a separate option. Transaction costs of different ESTs as CDM projects have not been included in the present analysis. The likely implications of transaction cost are, however, discussed qualitatively in a later section.

Table 1. Renewable and cleaner thermal technology options considered in the study

Country	Renewable options		Cleaner fossil fuel technology options
	Option	Maximum limit on new capacity, in megawatts (MW)	
Sri Lanka	Biomass	5,000	For all three countries, supercritical (coal), integrated gasification combined cycle, pressurized fluidized bed combustion, and combined cycle plants were considered.
	Small/mini hydro	300	
	Large/medium hydro	—	
	Wind	5,100	
Thailand	Biomass	4,819	
	Large/medium hydro	—	
	Small/mini hydro	—	
	Solar	300	
	Wind	300	
Vietnam	Biomass	4,746	
	Geothermal	400	
	Solar	6,000	
	Small and mini hydro	1,800	
	Wind	9,000	

Source: SLEMA (2004) for Sri Lanka data, SIIT (2004) for Thailand data, and IE (2004) for Vietnam data.

Table 2. Capital cost of candidate power plants considered in the study, in US $/kW at 2000 prices

Plant type	Country		
	Sri Lanka	Thailand	Vietnam
Pulverized coal	1,205	1,000	1,000
Supercritical coal	1,329	1,329	1,329
Integrated gasification combined cycle	1,420	1,420	1,420
Pressurized fluidized bed combustion	1,440	1,440	1,440
Combined cycle	686	557	600
Gas turbine	409	395	—
Oil steam	585	—	580
Biomass	1,510	1,510	1,510
Biomass integrated gasification combined cycle	1,626	1,626	1,626
Wind	1,200	1,960	1,000
Solar photovoltaic	5,500	5,500	5,500
Geothermal	—	—	2,140
Mini hydro	3,000	—	900
Small hydro	—	—	6,500

3. CO_2 reduction potential under the Clean Development Mechanism

Total CO_2 emissions reduction at different CER prices during the periods of 2006 to 2012 and 2006 to 2025 are presented in table 3 along with values of total CO_2 emissions in the base case (i.e., without the CDM). In Thailand, total CO_2 reduction potential during 2006 to 2025 would vary from 1,065 million tonnes at the CER price of US$5 per tonne of CO_2 (tCO_2) to 1,609 million tonnes at the CER price of $20/$tCO_2$, while in the case of Sri Lanka the corresponding figures would be 44 million and 113 million tonnes, respectively. The CDM potential in Vietnam would vary from 196,000 to 500,000 tonnes in the above CER price range. Thus, at the CER price of $5 (which is close to the average prevailing price), it would be cost-effective to reduce about 21 percent of the base case CO_2 emissions in Thailand, about 15 percent in Vietnam, and 24 percent in Sri Lanka. The total CO_2 reduction potential during 2006 to 2012 in Sri Lanka, Thailand, and Vietnam is much smaller at the CER price of $5, i.e., 3 million, 125 million, and 28 million tonnes, respectively.

Table 3. Total emissions in the base case and CO_2 emissions reduction at various CER prices, in million tonnes

Country	Period	CO_2 emission reductions at each CER price, US$/t$CO_2$							Total emissions in base case
		$2	$5	$8	$10	$12	$15	$20	
Sri Lanka	2006–2012	2	3	6	7	7	7	7	14
	2006–2025	11	44	101	101	102	103	113	185
Thailand	2006–2012	35	125	170	177	180	194	199	984
	2006–2025	252	1,065	1,325	1,415	1,441	1,528	1,609	5,111
Vietnam	2006–2012	12	28	48	58	63	69	79	304
	2006–2025	100	196	284	348	391	469	501	1,308

4. The role of fuel-switching versus renewable energy technologies (RETs) under the CDM

CO_2 emissions reduction from the power sector could be achieved through several options, which include fuel-switching in power generation and the use of more efficient power plants and renewable energy resources/technologies. It is of interest to examine the roles of different technological options for CO_2 reduction. We turn to this issue next by discussing the electricity generation shares of different technology options in the years 2012 and 2025 in the selected countries.

As can be seen in figure 1a, the main source of CO_2 reductions in Sri Lanka in 2012 (the final year of the first commitment period) at CER prices of up to $20 would be fuel-switching (from coal to oil).

Similar observations can be made on factors behind CO_2 reduction in 2025, except that the RETs option would now be optimally selected at the CER price of $15 and above (figure 2a).

In Thailand, fuel-switching (from coal to natural gas-based power generation) would be the main source of CO_2 emissions reduction in 2012 at CER prices of up to $20. RETs-based generation would also contribute to CO_2 emission reductions from $5 to $20 (figure 1b). Similar observation holds true for the year 2025 (figure 2b). Besides, oil-based generation would increase to a CER price of $20 by 2025.

In Vietnam, CO_2 emissions reduction would take place through fuel-switching (from coal to gas) at CER prices of $2 and above. In addition, the use of RETs (i.e., geothermal and small hydro) is found attractive even at the CER price of $5 (figure 1c). By 2025, fuel-switching (coal to gas), use of RETs, and more large hydro would all contribute to reducing CO_2 emissions even at a CER price of $5 (figure 2c).

Figure 1a.
Sri Lanka

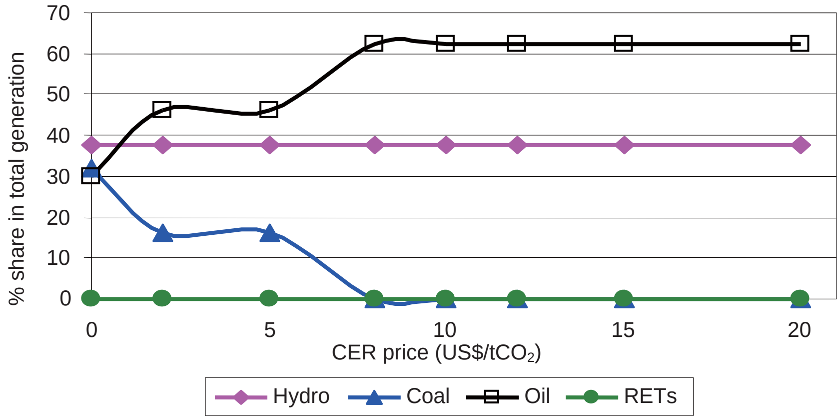

Figure 1b.
Thailand

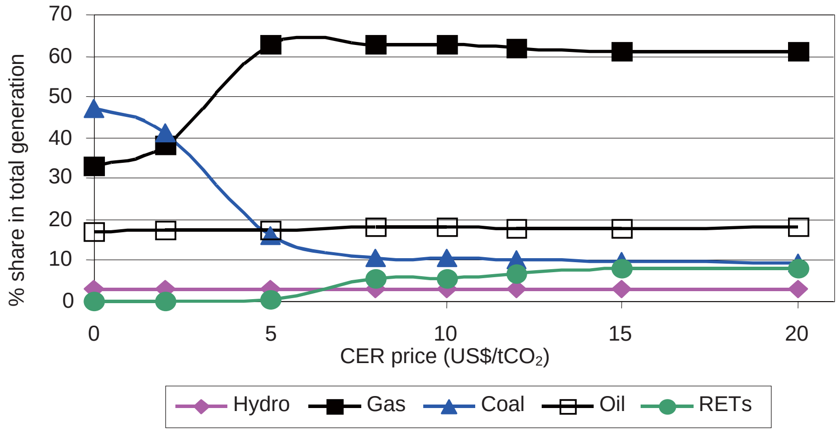

Figure 1c.
Vietnam

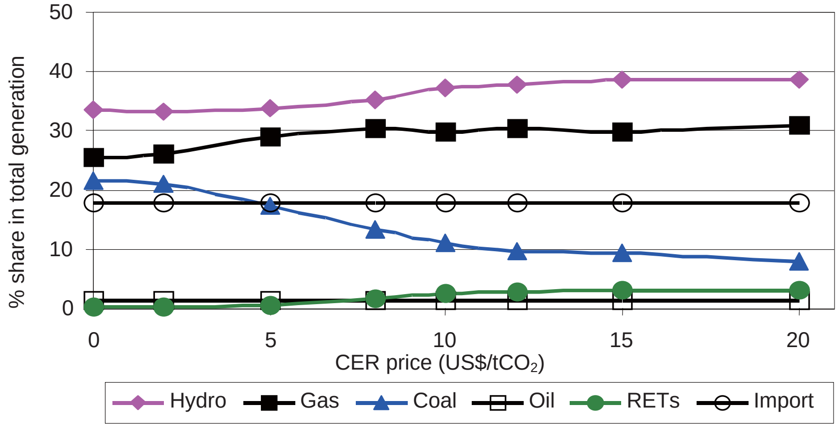

Figure 1. Shares in total power generation by fuel type in 2012

Figure 2a.
Sri Lanka

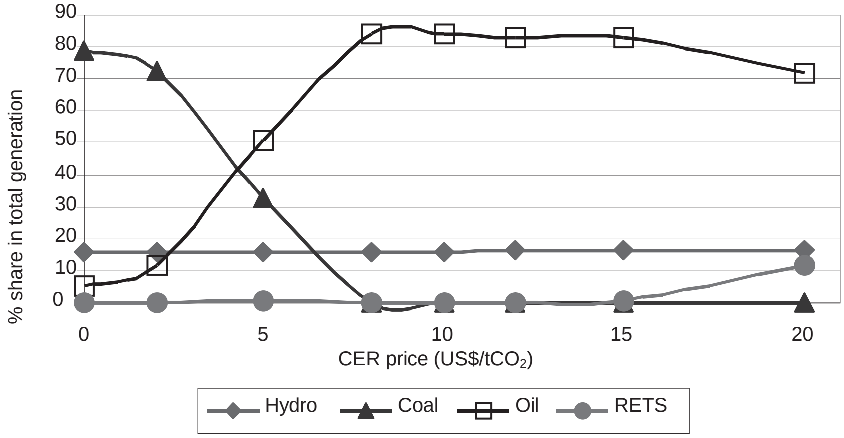

Figure 2b.
Thailand

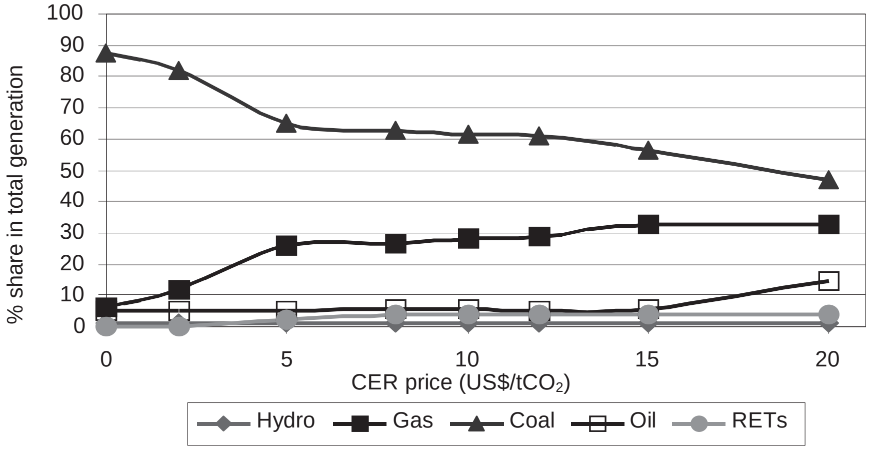

Figure 2c.
Vietnam

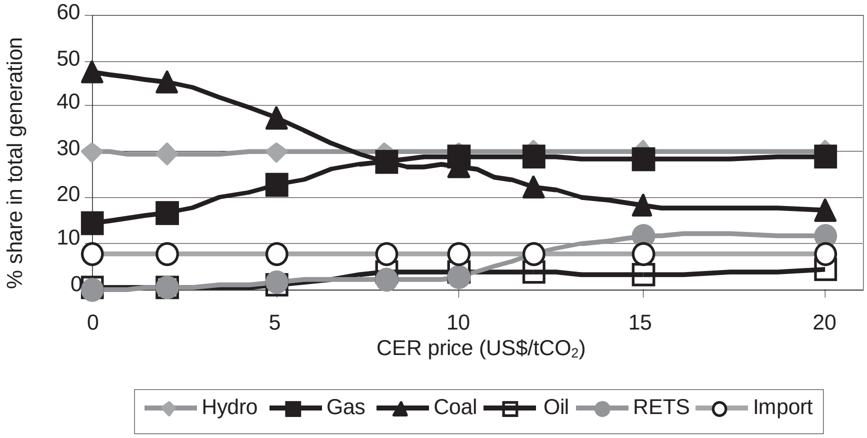

Figure 2. Shares in total generation by fuel type in 2025

Figure 3a.
Sri Lanka

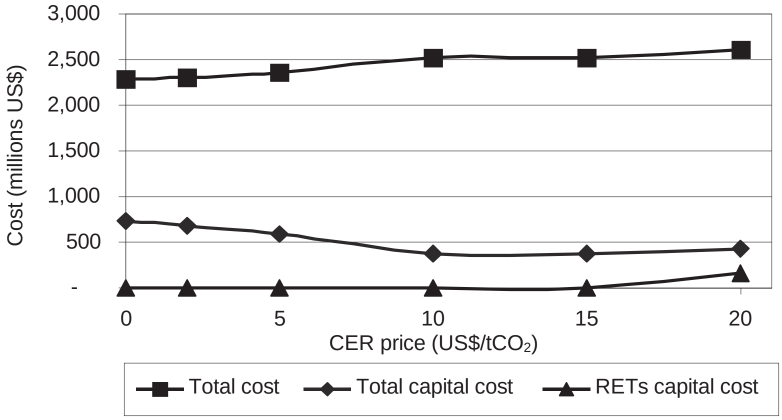

Figure 3b.
Thailand

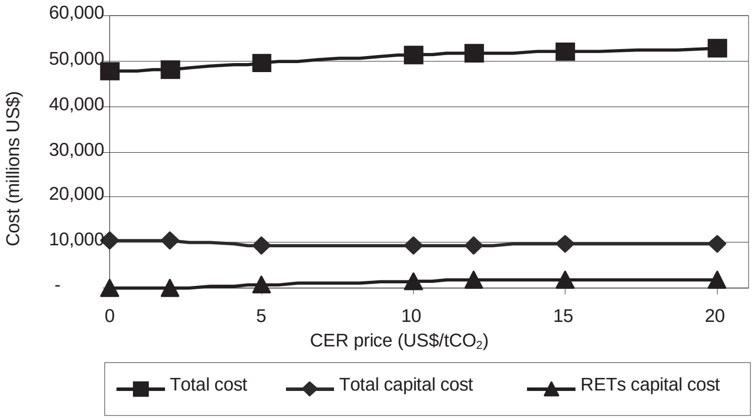

Figure 3c.
Vietnam

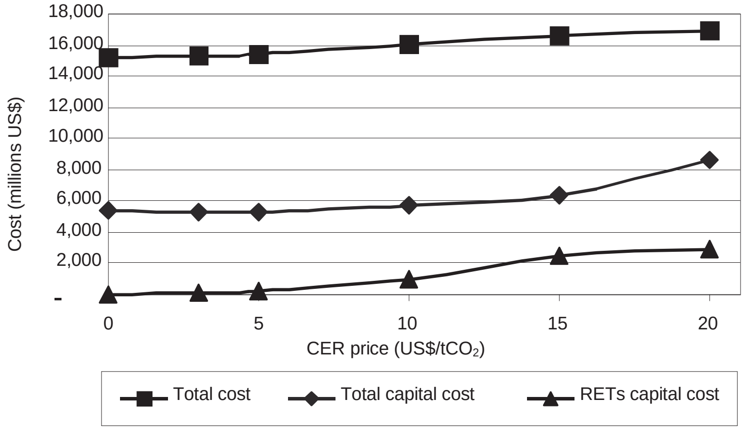

Figure 3. Capital- and total- costs during 2006–2025 at selected CER prices

A major finding of the foregoing analysis is that fuel-switching (from coal to gas in Thailand and Vietnam and from coal to oil in Sri Lanka) would be the most cost-efficient and predominant option for reducing CO_2 emissions from the grid-connected power system, not only at the prevailing CER prices of $3 to $6 (Lee 2003) but also at significantly higher prices of up to $20. The dominant role of fuel-switching continues not only until 2012 but also during the entire planning horizon of 2006 to 2025. It would be the only cost-efficient source of CO_2 reduction in Sri Lanka at prices of up to $15 until 2025, while it would be the only cost-effective option for CO_2 reduction in Thailand at CER prices up to $5.

The use of RETs would not be optimal in Sri Lanka even at a CER price of $15 by 2012, and this is so also by 2025. Power generation based on biomass would become optimal even at a relatively low CER price of $5 in Thailand. Similarly, geothermal-based electricity generation would become cost-efficient even at the CER price of $5 in Vietnam. Besides, the hydropower share would also increase at CER prices of $5 and above in the case of Vietnam. This is because, unlike Sri Lanka and Thailand, Vietnam has significant potential for additional hydropower generation.

As fuel-switching would be the efficient and dominant mode for CO_2 reduction at low CER prices, a question can be raised as to whether fuel-switching would result in the introduction of technologies that are different from the existing ones in these countries. To answer this question, the structure of capacity additions by type of power plants needs to be analyzed. Additions to generation capacity during 2006 to 2012 at different CER prices are presented in table 4, while table 5 presents the capacity additions during the entire planning horizon.

Table 4. Power generation capacity additions by plant type during 2006–2012, in megawatts (MW)

Country	Plant type	Fuel type	CER Price, US$/$tCO_2$				
			$0	$5	$10	$15	$20
Sri Lanka	Pulverized coal	Coal	600	300	0	0	0
	Combined cycle	Oil	0	0	300	300	300
	RETs	RE[a]	0	0	3	3	0
	Total addition (MW)		600	300	303	303	300
Thailand	Pulverized/supercritical coal	Coal	11,000	1,200	0	0	0
	Gas turbine	Gas	2,200	2,200	2,200	2,200	2,200
	Combined cycle	Gas	2,400	11,400	11,400	11,400	11,400
	RETs	RE	0	160	1,960	2,910	2,910
	Total addition (MW)		15,600	14,960	15,560	16,510	16,510
Vietnam	Pulverized/supercritical coal	Coal	1,300	700	0	0	0
	Combined cycle	Gas	1,440	1,440	1,440	1,440	1,440
	Import	Hydro	3,000	3,000	3,000	3,000	3,000
	Large hydro	Hydro	3,373	4,060	5,287	5,520	5,690
	RETs	RE	0	215	1,083	1,201	1,205
	Total addition (MW)		9,113	9,415	10,810	11,161	11,335

[a]Renewable energy.

Table 5. Power generation capacity additions by plant type during 2006–2025, in megawatts (MW)

Country	Plant type	Fuel type	CER price, US$/t$CO_2$				
			$0	$5	$10	$15	$20
Sri Lanka	Pulverized coal	Coal	3,600	1,500	0	0	0
	Combined cycle	Oil	0	1,800	3,300	3,600	3,300
	Gas turbine	Oil	735	875	840	455	210
	Large hydro	Hydro	40	40	40	89	89
	RETs	RE[a]	0	52	30	29	729
	Total addition (MW)		4,375	4,267	4,210	4,173	4,328
Thailand	Pulverized, IGCC,[b] and supercritical coal	Coal	65,000	46,000	45,500	45,500	35,500
	Gas turbine	Gas	2,200	2,200	2,200	2,200	2,200
	Combined cycle	Gas	6,000	22,800	22,800	22,800	33,000
	RETs	RE	0	1,960	2,910	3,085	2,985
	Total addition (MW)		73,200	72,960	73,410	73,585	73,685
Vietnam	Pulverized / supercritical coal	Coal	19,400	13,100	8,300	6,400	6,000
	Combined cycle	Gas	5,670	8,850	8,850	8,850	8,850
	Import	Hydro	3,000	3,000	3,000	3,000	3,000
	Large hydro	Hydro	12,722	14,014	14,714	13,514	13,514
	Diesel conventional	Diesel	0	580	1,450	1,450	1,450
	Oil steam	Oil	0	600	2,400	1,800	2,400
	RETs	RE	20	650	2,528	10,801	10,800
	Total addition (MW)		40,812	40,794	41,242	45,815	46,014

[a]Renewable energy.
[b]Integrated gasification combined cycle.

As can be seen from table 4, there would be an addition of 11,400 megawatts (MW) of combined cycle capacity at CER prices of $5 to $20 in Thailand. Combined cycle power plants are not new to Thailand; there already exists over 5,000 MW of such capacity in the country (EGAT 2003). A further 2,400 MW of such capacity would be added by 2012 in the base case (i.e., the zero CER price case). Thus, CDM projects based on fuel-switching (from coal- to gas-fired generation) cannot be expected to result in a significant transfer of technology to Thailand.

In Vietnam, additional coal-fired capacity requirement would decline from 1,300 MW in the base case to 700 MW during 2006 to 2012 at the CER price of $5; no such capacity would be added at a CER price of $10 and higher during the period. The reduction in coal-based generation capacity at the CER price of $5 would be compensated for by an addition of large hydro capacity. Altogether, 1,440 MW of combined cycle capacity would be added during the period in the base case as well as at CER price cases, while large hydro capacity of 4,060 MW and 5,690 MW would be added at CER prices of $5 and $20, respectively, as compared to the 3,000 MW that would be added in the base case. More additions of combined cycle and large hydro capacity would take place over a longer period of 2006 to 2025 (table

5). Like Thailand, however, Vietnam already possesses over 2,700 MW of combined cycle plants and more than 4,600 MW of hydropower capacity (IE 2004). Thus, the additions of the combined cycle and hydro plants under the CDM (i.e., at positive CER prices) may bring only marginal gains to Vietnam in terms of technology transfer.

In Sri Lanka coal-fired generation capacity would decline from 600 MW in the base case to 300 MW at the CER price of $5 from 2006 to 2012 (table 4), while it would decline from 3,600 MW in the base case to 1,500 MW at the CER price of $5 over the whole planning horizon; no coal-fired capacity would be added at a CER price of $10 and above (table 5). New requirements for increased coal capacity would be avoided by a significant addition of combined cycle oil-fired plants at CER prices of $5 to $20. The existing capacity of combined cycle plants in Sri Lanka is relatively small (328 MW), and an addition of new, large-scale, combined cycle capacity would provide an opportunity to build significant capacity in installation, operation, and maintenance of such plants. Thus, technology transfer in the form of human resource development for installation, operation, and maintenance of such plants is expected to take place in the country through the CDM.

5. The potential of renewable energy technologies under the CDM

Table 6 shows the cost-effective levels of adding power generation capacity by type of RET in Sri Lanka, Thailand, and Vietnam at selected CER prices during the period of 2006 to 2012 (i.e., the end of the first commitment period of the Kyoto Protocol), while table 7 presents the corresponding figures during the entire planning horizon (2006–2025).

Table 6. RET-based generation capacity additions at selected CER prices during 2006–2012, in megawatts (MW)

		CER price, US$/t$CO_2$				
Country	Technology	$0	$5	$10	$15	$20
Sri Lanka	Biomass	0	0	0	0	0
	Small hydro	0	0	0	0	0
	Solar	0	0	0	0	0
	Wind	0	0	3	3	0
	Total RETs (MW)	0	0	3	3	0
Thailand	Biomass	0	160	1,960	2,910	2,910
	Solar	0	0	0	0	0
	Wind	0	0	0	0	0
	Total RETs (MW)	0	160	1,960	2,910	2,910
Vietnam	Biomass	0	0	0	0	0
	Geothermal	0	20	40	120	120
	Small hydro	0	195	315	281	285
	Solar	0	0	0	0	0
	Wind	0	0	728	800	800
	Total RETs (MW)	0	215	1,083	1,201	1,205

As can be seen from table 6, adding new grid-connected solar power generation would not be cost-effective in the three countries during the first commitment period, even at the CER price of $20. In addition, biomass-based power generation would not be an optimal technology for 2006 to 2012 in Sri Lanka and Vietnam, while the wind power option would not be attractive in Thailand, even at the CER price up to $20. In Sri Lanka, the addition of new grid-connected small hydro capacity would not be attractive during the period for the entire CER price range considered in the study (i.e., up to $20). Furthermore, only an insignificant addition of wind-generating capacity would take place in the country at CER prices of $10 and $15. In the case of Thailand, it would be optimal to add only biomass-based power plant capacity to the power grid at the CER price of $5 and above during the period. In Vietnam, some small hydro and geothermal would be cost-effective at $5 and above, while wind would be attractive at $10 and above. Overall, the non-hydro RET options do not play a major role at CER prices below $10 during the period.

Table 7. RET-based generation capacity additions at selected CER prices during 2006–2025, in megawatts (MW)

		CER price, US$/t$CO_2$				
Country	Technology	$0	$5	$10	$15	$20
Sri Lanka	Biomass	0	10	0	20	480
	Small hydro	0	0	0	0	0
	Solar	0	0	0	0	0
	Wind	0	42	30	9	249
	Total RETs (MW)	0	52	30	29	729
Thailand	Biomass	0	1,960	2,910	3,085	2,985
	Solar	0	0	0	0	0
	Wind	0	0	0	0	0
	Total RETs (MW)	0	1,960	2,910	3,085	2,985
Vietnam	Biomass	0	0	0	0	0
	Geothermal	20	400	400	400	400
	Small hydro	0	245	1,400	1,401	1,400
	Solar	0	0	0	0	0
	Wind	0	5	728	9,000	9,000
	Total RETs (MW)	20	650	2,528	10,801	10,800

Would the result be different over a longer period of time, i.e., after the first commitment period? As can be seen in table 7, grid-connected solar and wind capacity would continue to not be cost effective in Thailand until 2025 (i.e., the end of the planning horizon of this study) even up to the CER price of $20. Biomass power generation would be a cost-effective option in Thailand at CER prices of $5 and higher, and in Sri Lanka at prices of $15 and higher. The case of Vietnam differs again from Thailand and Sri Lanka in that geothermal, small hydro, and wind would be cost-effective in Vietnam, even at a relatively low CER price of $5. In summary, non-hydro RETs would not contribute significantly in the power sector at the prevailing market price of CERs in the three countries (i.e., $3 to $6). This would also be the case at higher prices of up to $15 in Sri Lanka and Thailand and up to $10 in Vietnam. At the CER price of $10, the share of all non-hydro capacity in total power generation capacity addition during 2006 to 2025 would be 0.7 percent in Sri Lanka, 3.9 percent in Thailand, and 2.7 percent in Vietnam.

6. Capital implications of the CDM in the power sector

Many developing countries are faced with a shortage of capital for financing their energy and power sector projects. In this context, it is natural to ask whether the CDM would necessarily help alleviate the problem of capital shortage in their energy and power sectors. In other words, would the CDM reduce the total capital requirements? The answer to this question depends largely on the type of CDM projects implemented. If they are of the fuel-switching type in the power sector, e.g., using combined cycle gas-fired plants, instead of the more capital-intensive, coal-fired steam turbine and super-critical plants, then total capital requirements would indeed be reduced, although the total cost of electricity production may increase due to increase in fuel cost (i.e., higher gas or oil cost). On the other hand, if the CDM mainly involves RETs-based power generation projects such as wind or solar power plants, then it is possible for the total capital requirement of the power sector to increase. This could happen for two main reasons. First, most RETs are normally more capital-intensive than the thermal alternatives. Second, the addition of RETs-based plant capacity like wind and solar may not reduce the capacity requirement of other types by the same amount, due to the intermittent nature of energy availability from such resources; as a result, total additional capacity requirement of the power sector may be increased. This can be seen in the case of Vietnam (see table 5). At the CER price of $15, not only was there a significant level of RETs capacity added but the total additional capacity required in the power sector was also increased by 12 percent in comparison to that in the base case.

Figures 3a to 3c show the discounted capital and total costs during 2006 to 2025 in the power sectors of Sri Lanka, Thailand, and Vietnam at different CER prices along with the capital cost of RETs-based power plants. Compared to the base case, the total capital cost in the power sector of Sri Lanka would be reduced by 19.7 percent and about 48.9 percent at CER prices of $5 and $10, respectively. Similarly, in Thailand, the total capital cost would be reduced by about 9.7 percent and 10.5 percent at CER prices of $5 and $10, respectively. This is mainly because, at these CER prices, CO_2 emissions reduction would take place mainly through fuel-switching, i.e., using less capital-intensive, oil-fired combined cycle plants instead of coal-fired thermal plants in Sri Lanka and gas-based combined cycle plants in Thailand. Unlike in Sri Lanka and Thailand, at CER prices of $10 and $15, the total investment required in Vietnam's power sector would increase by about 7 percent and 18 percent, respectively, as compared to that in the base case.

The upshot of this discussion is that the CDM may help alleviate the capital shortage problem in the power sector of a developing country when it involves the implementation of projects like fuel-switching. On the other hand, implementation of RETs-based CDM projects (especially wind and solar) may result in a higher investment requirement at the sectoral level than in the base case. One implication of this is that low-income countries with a serious shortage of capital may be particularly handicapped in exploiting CDM opportunities to any significant level.

It should be noted that the foregoing analysis presents an optimistic assessment of CDM potential at the selected CER prices because no transaction cost was considered in determining the optimal electricity generation options and associated level of CO_2 emissions reduction. CDM potential could be smaller and the choice of cost-effective technology options could differ if transaction costs associated with different activities in the CDM project cycle are considered. In particular, the inclusion of transaction costs would further reduce the viability of most RETs, as their transaction costs per unit of emissions reduction are high due to their relatively small scale. According to Michaelowa et al. (2003), transaction costs per tonne of CO_2 equivalent can vary widely with project size, i.e., from 0.1 euros (€) per tonne of carbon dioxide (tCO_2), in the case of very large hydro projects, to €1,000/tCO_2 for micro projects (like solar photovoltaics). Furthermore, they report that under current estimates of world market prices for greenhouse gas emission permits, projects with annual emissions reductions of less than a 50,000 tCO_2 equivalent are unlikely to be viable. Thus, renewable power projects based on solar photovoltaics, wind, and biomass may not be viable if their size (i.e., capacity) is below 37 MW, 22 MW, and 8 MW, respectively.[1] In the context of many low-income developing countries, however, RETs-based projects are normally not as big.

7. Barriers to environmentally sound technologies and the CDM

As the CDM is a market-based mechanism, a necessary condition for implementation of a CDM project is its economic viability. The CER benefit under the CDM could improve the economics of a project, but implementation of a project under the CDM could still be difficult due to a number of barriers. Many of the barriers that are typical to the adoption of environmentally sound technologies (ESTs) would therefore also be applicable to CDM projects. In the power sector, the key barriers in many developing countries (DCs) include (1) regulatory/institutional barriers, (2) barriers related to foreign investment, (3) lack of access to financing, (4) technical barriers, and (5) CDM process-specific risk and uncertainty. The discussion in this section is made in the broader context of DCs rather than being specific to the three selected countries.

Institutional and regulatory barriers. Traditionally in many developing countries, a single, vertically-integrated public utility is involved in electricity generation, transmission, and distribution. An absence of laws and policies that allow private firms to produce electricity and that mandate the public electric utilities to purchase electricity produced by private firms or independent power producers (IPPs) prevent investment by private parties in cleaner and climate-friendly power generation technologies. In addition, a lack of policies on determining utilities' buyback rates for electricity produced by IPPs can be a barrier to the implementation of power projects by private parties; the same applies to projects under the CDM.

Barriers to foreign investment. Lack of clear policies and regulation on foreign investments serves as a barrier to CDM projects to be implemented through such investments. In many countries an absence of clearly defined laws and policies governing foreign investment—including policies on the transfer of income earned by foreign investments, as well as foreign exchange regulations—acts as the main barrier

1. These estimates were obtained by assuming a baseline emission factor of 900 g/kWh for a coal-burning power plant and capacity factors of 0.17, 0.30, and 0.79 for solar photovoltaic, wind, and biomass power plants, respectively. Capacity factor is defined as the ratio of average power supplied by a power plant to total capacity of the plant.

to foreign capital inflows. Clearly, a lack of policies supportive of foreign investment will reduce the level of implementation of projects under the CDM.

Many developing countries, especially those in the low-income group, also face high financing costs due to higher risks attached to investments in these countries. Unless the higher-risk premium in the cost of financing can be more than compensated for by savings in project costs, CDM investments may not be profitable. This implies that CDM activities in low-income countries will be mostly limited to relatively high financial return projects.

Lack of access to financing facilities. Potential developers of RETs and energy-efficiency improvement (EEI) projects often lack access to credit facilities for financing the projects in many DCs. In many cases financial institutions are either unprepared (as a matter of policy) or lack expertise in dealing with investments related to RETs and EEI projects.

Technical barriers. In the context of the demand-side EEI projects in many DCs, these include lack of technical services (repair and maintenance), poor quality of EEI equipment ("substandard products"), and inadequate knowledge on operating EEI projects. In the case of electrical equipment, power quality could also be a major barrier. For example, compact fluorescent lamps (CFLs), which use 75 to 80 percent less electricity compared to incandescent lamps, may not operate properly below certain voltages (i.e., 160 to 170 volts), yet it is not uncommon to occasionally find supply voltages below such levels in many developing countries, especially in rural areas of low-income countries.

CDM process-specific risk and uncertainty. Most of the barriers typically faced by investors in EST-based projects also apply to projects under the CDM. In addition, the proponents of CDM projects have to satisfy at least two additional requirements: the sustainable development criteria and the additionality criterion.[2] Sustainable development criteria can be country-specific, and comprehensive tests for them in the context of the CDM are still under development in most countries. Until the sustainable development criteria are formulated in operational terms (which yet remains to be accomplished in most developing countries), CDM projects face uncertainties as to their approval by the host countries. Similarly, CDM projects also face uncertainties related to approval of proposed methodologies by the CDM Executive Board for determining their additionality. It should, however, be noted that these uncertainties may be reduced over time with the rise in the number of CDM projects implemented, as the formulations of sustainable development and additionality criteria would become more transparent in the process.

In the absence of an agreement beyond the first commitment period, CDM projects are also subject to uncertainties as to the validity of CERs after the first commitment period is over. Large-scale investment in capital-intensive projects with a long life can be especially sensitive to such uncertainty.

8. Conclusion

This paper has analyzed the CDM potential of major technology options (fuel-switching and renewable energy-based power generation) in the power sector of Sri Lanka, Thailand, and Vietnam. The analysis shows that fuel-switching (i.e., from coal to gas or oil) would be the more cost-efficient

2. For joint implementation and CDM projects, emissions reductions must be additional to those that would otherwise occur.

and predominant option for CO_2 reduction at low CER prices (in all three countries at CER prices up to $20). Most renewable energy (biomass, solar, and wind) power generation projects would not be cost-effective under the CDM, not only at the prevailing CER market price (i.e., 3 to 6 dollars) but also at significantly higher prices. It is found that from 2006 to 2025 the combined share of non-hydro RETs in total capacity addition in the power sector would be 0.7 percent in Sri Lanka, 2.75 percent in Vietnam, and 3.9 percent in Thailand at the CER price of $10.

The analysis also shows that the total capital requirement of the power sector would be lower than that at the base case (i.e., without the CDM) at low CER prices due to the predominant role of fuel-switching in CO_2 emissions reduction through replacement of coal-fired power plants with less capital-intensive combined cycle plants. On the other hand, the use of a significant level of RETs-based power plants under the CDM could cause the opposite effect, i.e., capital needs could be higher than in the base case (as was found in the Vietnam case at the $20 CER price).

The economic potential of the CDM in developing countries may not be fully attainable due to the existence of institutional, regulatory, and other barriers, which either increase the CDM project cost or make the implementation of CDM projects practically infeasible.

It should be noted that the quantitative analysis of the CDM potential and choice of technological options in this paper was carried out by ignoring transaction costs. Incorporation of transaction costs is expected to further reduce the economic viability of the power generation options based on RETs, which are mostly decentralized and normally smaller in size than the thermal and large hydro options. It should also be noted that the present analysis has not considered the role of demand-side energy-efficiency improvement options for CO_2 emissions reduction at different CER prices. We intend to deal with these issues in subsequent studies.

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