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Assessment of emissions reduction and reduction credits

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Electricity sector no-lose targets in developing countries for post-2012: Assessment of emissions reduction and reduction credits

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Abstract

Sectoral no-lose target has been suggested as one way to overcome weaknesses of the current clean development mechanism (CDM) and to encourage structural changes and significant reduction of CO_2 emissions in carbon-intensive sectors in developing countries. The purposes of this paper are to 1) propose a method for formulating national sectoral baselines and crediting targets for the electricity sector for post-2012; 2) assess the amount of emissions that could be reduced compared to the baselines by seven developing countries with large CO_2 emissions from electricity generation based on options of increased efficiency fossil power plant and decreased share of fossil electricity and 3) estimate the amount of emissions reduction credits that could be generated based on the proposed targets.

The national electricity sector crediting baseline from 2005-2020 for each country is set as a linear line starting from the average emission intensity in year 2005 of all power plants (average operating margin in 2005) to a weighted average emission intensity of the current average operating margin and the most recent capacity additions comprising 20 percent of the total generation (build margin). Two crediting targets are proposed: Dynamic targets are formulated the same way as the baselines but with a different weighting factor, and Fixed target are set constant throughout the same period. These baselines and targets build upon an existing method for calculating baseline emissions factor for a CDM project activity that supplies electricity to the national grid, taking into account different countries' average efficiency of fossil power plants and generation mix.

It is found that in order to reduce the total annual average emissions by 10 percent compared to the baselines, one option requires that (1) coal and gas power plants added during the period 2005-2020 have a 40 and 50 percent average conversion efficiency, respectively, and (2) the new capacity added in the different countries during 2005-2020 delivers on average 12 percent less coal based electricity than the build margin in 2005. Under this option, 410-540 $MtCO_2$/year of reduction credits could be generated during 2012-2020. Among the seven countries, most of the total credits would be generated in China. The distribution of total credits among the studied countries is proportional to their share of the total emissions reduction. The results imply that substantial efforts from both private sectors and governments in these countries are needed to make radical emission reductions in the electricity sector. The sectoral crediting target could provide substantial incentives to stimulate the installation of new generation capacities that are more efficient and less carbon intensive.

Keywords: sectoral no-lose targets, post-2012, electricity sector, developing countries

1. Introduction

The Clean Development Mechanism (CDM) under the Kyoto Protocol allows industrialized countries to earn certified emissions reduction credits (CERs) generated through projects implemented in developing countries. These CERs can be used to offset some of the domestic greenhouse gas (GHG) emissions to meet emission reduction targets under the Kyoto Protocol. The CDM has become by far the world's largest offset carbon market with a total value of several billion euros. More than 4,200 projects have been registered or are in the process of validation and registration. An annual emissions reduction of 590 million tons of CO_2-equivalent ($MtCO_2$-eq.) and a cumulative reduction by 2012 of 2.9 billion tons of CO_2-eq ($GtCO_2$-eq.) are expected from these projects. More than 1,100 projects have been registered. The cumulative issuance expected by 2012 is 1.5 $GtCO_2$–eq.(Fenhann, 2008).

Nevertheless, the CDM has been criticized for various issues. First, due to its design as a project-based mechanism, the CDM is unable to engage developing countries in ways that would lead to structural changes and significantly influence the energy system development (Wara and Victor, 2008; Sterk, 2008). Second, many CDM projects lack credibility regarding their environmental integrity objectives. Emission reductions claimed by the CDM projects are not necessarily real and additional (Schneider, 2007; Wara and Victor, 2008; IRN, 2008). To demonstrate additionality of a CDM project is to answer the question as to whether the project would not have been implemented in the future in the absence of the CDM. If a CDM project is not additional but nevertheless is registered as a CDM project, the issuance of CERs results in an increase in global GHG emissions (Schneider, 2007).

In addition, the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) working group III has recently indicated an urgent need for scaling up emissions reduction in the energy sector worldwide, especially in developing countries. The report noted that "With current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades: CO_2 emissions between 2000-2030 from energy use are projected to grow 45 to 110 percent over the period. Two-thirds to three quarters of this increase is projected to come from non-Annex I countries" (Ward, 2008).

Several approaches have been proposed for engaging developing countries within a post-2012 climate regime, with the aim to reach a substantial deviation from a baseline development pathway. (Wara and Victor, 2008; Sterk, 2008; Ward, 2008). Sectoral no-lose targets have been proposed as one sectoral approach to overcome the weaknesses of the current CDM and encourage structural changes and radical reductions of CO_2 emissions in carbon-intensive sectors in developing countries. Through non-binding (no-lose) sectoral crediting targets, developing countries could voluntarily reduce their emissions and gain financial support from developed countries if they do better than the target. No penalties would occur if the target is not met. The target could be set in relation to national emission intensities stimulating developing countries to continue their development in a less carbon intensive direction. The target would be set below the emissions level estimated for a "business as usual" scenario and could be negotiated and approved at the international level. Reductions below the target would generate emissions reduction credits (see Figure 1) (Ward, 2008). A minimum value of the credits might be set for a certain crediting period. In this way, the developing countries would have incentives for reducing their own emissions.

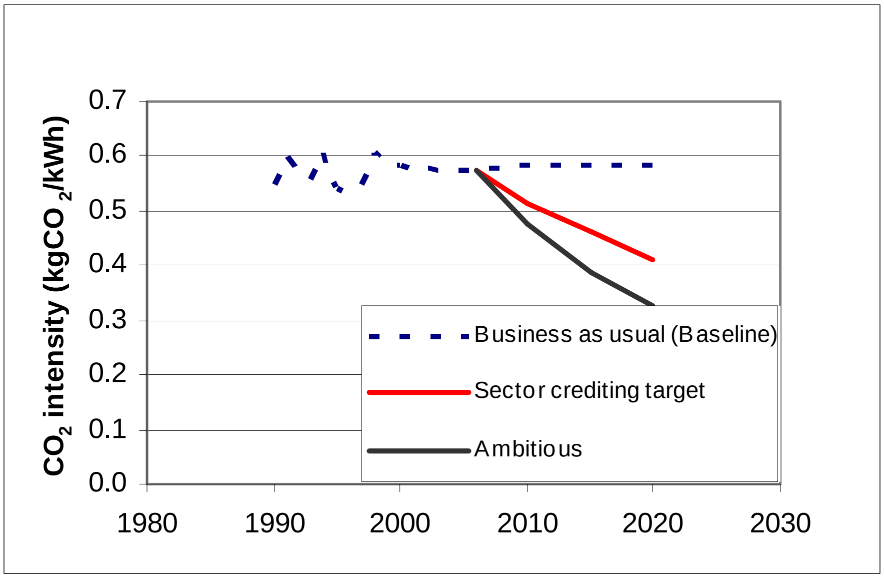

Figure 1. A hypothetical CO_2 intensity baseline and crediting target for a developing country. The "ambitious scenario" illustrates a CO_2 intensity reduction that goes beyond what is defined in the crediting target and that would generate emissions reduction credits for the developing country (Ward, 2008).

Sectoral no-lose targets have been discussed in particular with reference to the electricity sector, which makes a large and rapidly growing contribution to the total CO_2 emissions from developing countries. Several analyses of CO_2 emissions reduction potentials and options in the electricity sector in developing countries – and especially China – have been made (Cai et al., 2005; Kahrl and Roland Holst; 2006; Elzen et al, 2007; Elzen et al, 2008; Höhne et al, 2005)). Cai et al. (2005) reported that the emissions reduction potential in electricity sector in China corresponded to 85-350 $MtCO_2$/year. Demand side management and circulating fluidized bed combustion (CFBC) were suggested to be employed first, followed by the construction of supercritical power plants and retrofitting of conventional thermal power plants to lower their CO_2 intensity. Cai et al. (2005) also proposed that the intensity reduction target for China could be set within the range 4.2-19.4 percent below the level year 2000, depending on the implementation of various mitigation options. Elzen et al. (2008) analyzed sectoral emissions reduction allocation for both Annex-1 and non-Annex-1 countries in scenarios reaching 450 and 550 ppm CO_2-equivalent stabilization, based on a staged sectoral approach (Triptych approach). They concluded that non-Annex 1 countries would need to reduce their emissions from all relevant sectors by 13-19 percent in 2020. Kahrl and Roland Holst (2006) estimated that by meeting power plant efficiency goals and expanding alternatives to coal-fired generation according to a plan of the Chinese National Development Reform Commission (NDRC), China could reduce its CO_2 emissions from coal-fired power plants by approximately 840 Mt/year in 2020 against a baseline where electricity demand grows as fast as Gross Domestic Product (GDP) from 2005-2020.

However, these analyses assumed different baselines and scenarios and no standard method for setting electricity sector baselines and crediting targets for developing countries has been proposed. The CDM executive board has approved a standard method for the calculation of a baseline emission factor to be used for crediting the displacement of grid-connected electricity generation (UNFCCC, 2007), but this method was designed and used only for the CDM project activities.

The purposes of this paper are to 1) propose a method for formulating national sectoral baselines and crediting targets for the electricity sector for post-2012; 2) assess the amount of emissions that could be reduced compared to the baselines by seven developing countries with large CO_2 emissions from electricity generation based on options of increased power plant efficiency and decreased share of fossil electricity and 3) assess the amount of emissions reduction credits that could be generated based on the proposed targets. The assessment is made using a scenario analysis.

The ten developing countries with the largest CO_2 emissions from electricity generation in 2005 were (in order of the magnitude of emissions) China, India, South Africa, South Korea, Saudi Arabia, Mexico, Iran, Indonesia, Kazakhstan and Thailand (IEA, 2007). Saudi Arabia, Iran and Kazakhstan were not included in the study due to lack of data. The total amount of emissions from electricity generation from the seven countries included in the study accounted for 75 percent of the total amount of emissions from electricity generation in all non-Annex I countries in 2005.

The paper is structured as follows: Section 2 gives an overview of the electricity sector in the seven developing countries considered. Section 3 outlines the methodology and data used. Section 4 presents and discusses the results. Section 5 presents the conclusions and policy implications.

2. Overview of the electricity sector in the seven developing countries

The share of coal-based electricity in 2005 was particularly high in South Africa (90 percent), China (80 percent) and India (70 percent). The share was about 40 percent in Indonesia and South Korea, and below 20 percent in Mexico and Thailand (Figure 2). During the period 1980-2005, the share of coal-based electricity increased in China, India, Indonesia, South Korea and Mexico, while it was roughly constant in South Africa and decreased in Thailand (Figure 2). The share of oil-based electricity decreased during the same period in all the countries except Indonesia. The share of oil-based electricity in 2005 was about 30 percent in Indonesia and Mexico, and less than 10 percent in the other four countries. Natural gas increased substantially in Thailand, where it accounted for about 70 percent of the electricity generation in 2005. Indonesia had a period of rapid growth 1992-96 reaching about 40 percent of total electricity, but this share then decreased to about 15 percent in 2005. Mexico increased from about 15 percent natural gas based electricity to about 40 percent in 2004 (somewhat lower in 2005). India and South Korea increased their share of natural gas in electricity generation, from a very low level to about 10 and 15 percent, respectively. In China, natural gas based electricity has remained at a very low level throughout the period.

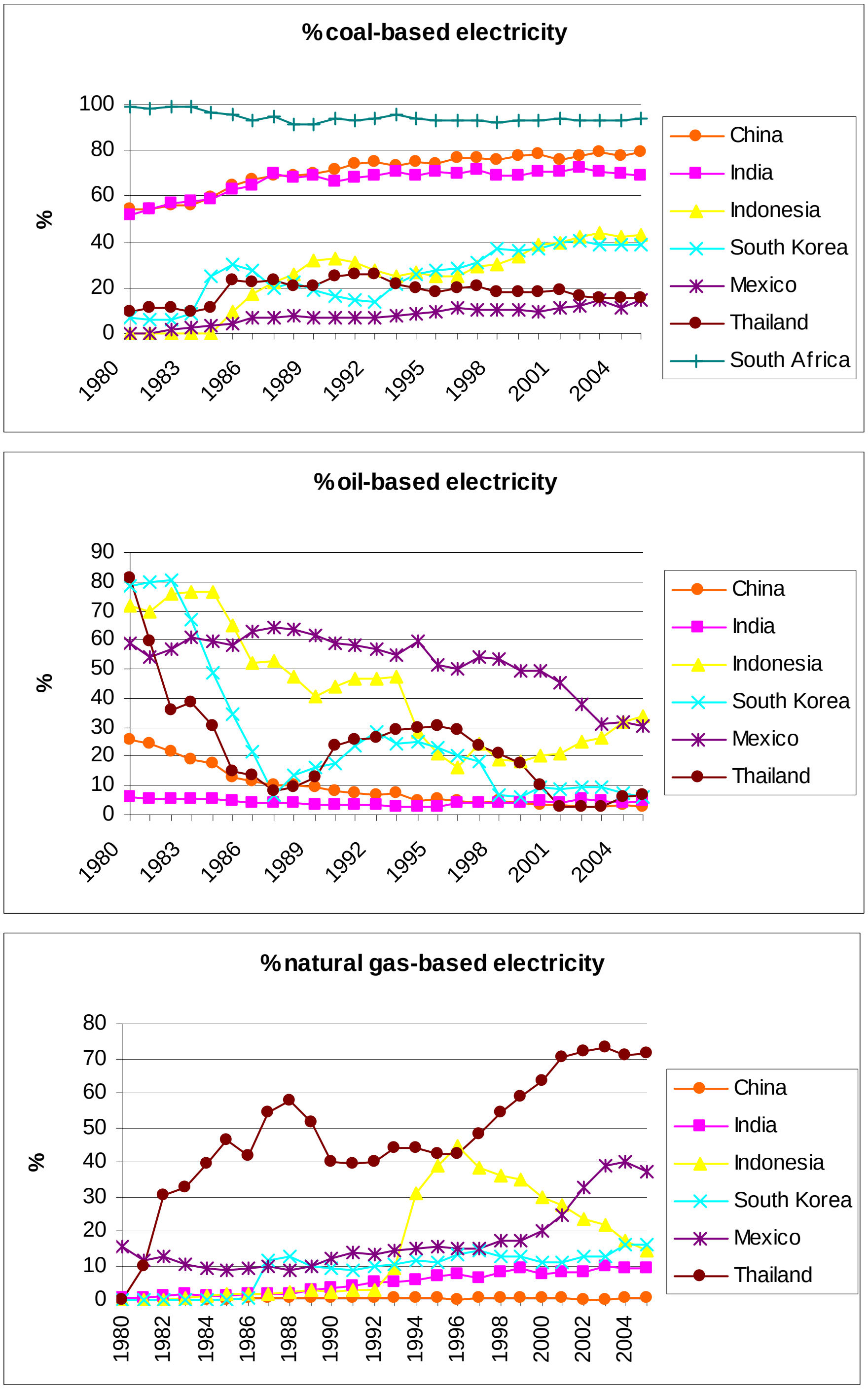

Figure 2. Trend of the share of fossil-based electricity of seven developing countries during 1980-2005 (data taken from (IEA, 2007))

Common for all the seven countries is that the share of fossil-based electricity did not decrease at all during 1990-2005. The change in the specific share of coal, oil and gas-based electricity over the period can be attributed to fossil fuel switching. Stated differently, the development of renewables-based electricity did not significantly affect the share of fossil-based electricity in these countries. Moreover, the share of all fossil electricity was very large in 2005 (90 percent in South Africa, Indonesia and Thailand, 80 percent in China, India and Mexico, and 60 percent in South Korea). Thus, these countries continue to rely heavily on fossil fuels for power generation.

The national average carbon intensity of the electricity sector in 2005 was high (800-1,000 gCO_2/kWh) in India, South Africa, China, which rely heavily on coal for power generation (Figure 3). During the period 2001-2005 the average carbon intensity increased in these three countries and Indonesia but decreased in Mexico, Thailand, and South Korea, partly due to a substantial increase in the share of gas-based electricity and a substantial decrease in the share of coal and oil-based electricity generation (Table 1).

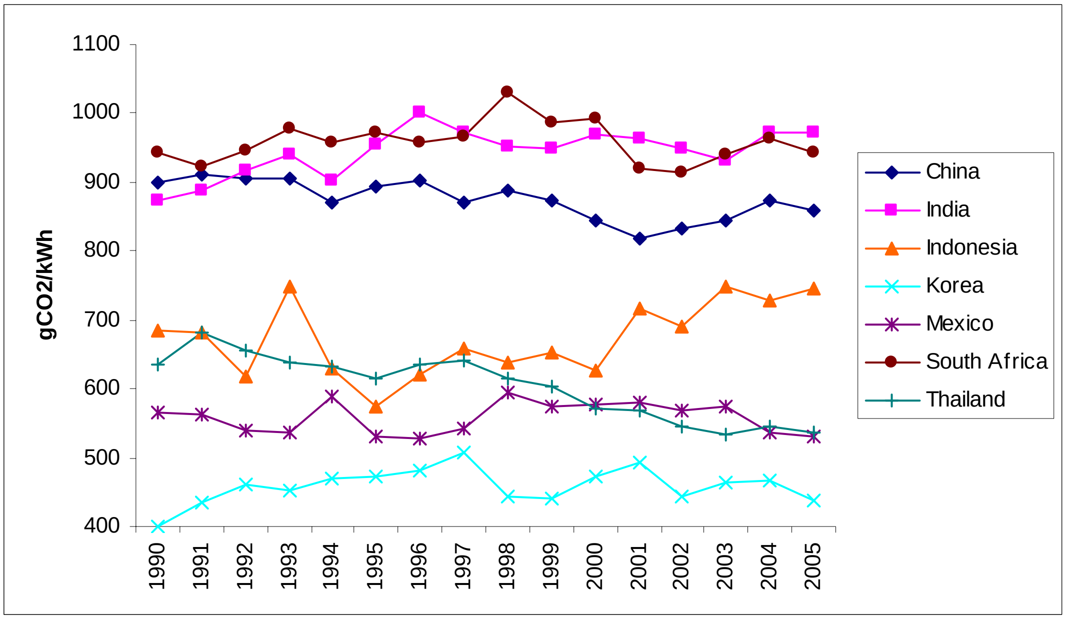

Figure 3. National average carbon intensity of the electricity sector of seven developing countries during 1990-2005 (our own calculation based on data taken from (IEA, 2007))

3. Methodology and data

3.1 Proposed method for setting baselines and crediting targets in electricity sector

Our proposed method for setting baselines and crediting targets for the electricity sector builds upon the existing method for calculating baseline emissions factor for a CDM project activity that substitutes electricity from the grid (UNFCCC, 2007). In the CDM method, the baseline CO_2 emissions factor for the displacement of electricity generated by power plants in an electricity system for a crediting period is determined by a combined margin (CM) emissions factor, which is a weighted average of an operating margin (OM) and a build margin (BM) emissions factor and calculated as follows.

$$CM = OM * W_{OM} + BM * W_{BM}$$

Where:
OM = Emissions factor (gCO_2/kWh) of a cohort of power plants that is representative of the existing power plants whose electricity generation would be affected by a proposed CDM project activity
W_{OM} = Weighting of average operating margin emissions factor (%)
BM = Emissions factor (gCO_2/kWh) of a cohort of power units that is representative of the type of power units whose construction would be affected by the proposed CDM project activity
W_{BM} = Weighting of build margin emissions factor (%)

The CDM method sets W_{OM} =0.5 and W_{BM} =0.5 for the first crediting period and W_{OM} = 0.25 and W_{BM} = 0.75 for the second and third crediting period (2012-2026) (UNFCCC, 2007).

Similar to the CDM method, we use a linear change of national baseline and crediting target (dynamic baseline and crediting target) from 2005-2020. That is, the baseline and crediting target are set to either increase or decrease from an average operating margin carbon intensity in 2005 to a combined margin carbon intensity in 2020. But the weighting factors for the baseline and crediting targets are different.

In the CDM method, an operating margin (OM) can be calculated in four ways; 1) Simple OM 2) Simple-adjusted OM 3) Dispatch data analysis OM 4) Average OM. The difference between the simple and average OM is that the simple OM excludes low-cost and must-run power plants while the average OM includes all power plants serving the grid. Dispatch data analysis OM is determined based on the power units that are actually dispatched at the margin during each hour where the project is displacing electricity. Since we consider the national average carbon intensity of all power plants serving the grid, we use an average OM.

The average operating margin carbon intensity of the electricity sector of 2005 (AOM_{2005}) is calculated as follows:

$$AOM_{2005} = \frac{C_{TOT,2005}}{E_{TOT,2005}}$$

Where:

$C_{TOT,\ 2005}$ = total CO_2 emissions from electricity generation from all power plants serving the grid in 2005
$E_{TOT,\ 2005}$ = total electricity generation (kWh) from all the power plants in 2005.

The combined margin intensity in 2020 is estimated at a weighted average emission intensity of the average operating margin in 2005 and the build margin in 2005 and formulated as follows:

$$CM_{2020} = AOM_{2005} * W_{AOM} + BM_{2005} * W_{BM}$$

$$BM_{2005} = \frac{\sum_{i=1}^{m}\left(EG_{m,2005} * EF_{EL,m,2005}\right)}{\sum_{i=1}^{m} EG_{m,2005}}$$

Where :

BM_{2005} = Build margin CO_2 emission factor in year 2005 (or the most recent year for which power generation data are available) (gCO_2/kWh)
$EG_{m,2005}$ = Net quantity of electricity generated and delivered to the grid by power unit m in year 2005 (kWh)
$EF_{EL,m,2005}$ = CO_2 emission factor of power unit m in year 2005 (gCO_2/kWh)
m = Power units included in the build margin (either the five power units that have been built most recently, or the most recent power capacity additions in the electricity system that comprise 20 percent of the total generation; the alternative that comprise the larger annual generation is used)

The CO_2 emission factor of each power unit m ($EF_{EL,m,2005}$) can be calculated:

- Based on data on fuel consumption and net electricity generation of each power plant/unit (Option A), or
- Based on data on net electricity generation, the average efficiency of each power unit and the fuel types used in each power unit (Option B), or
- Based on data on the total net electricity generation of all power plants serving the system and the fuel types and total fuel consumption of the electricity system (Option C)

Option A is preferred and is used if fuel consumption data are available for each power plant/unit. In other cases, option B or C is used.

The weighting factors for the baseline and crediting targets are set to be different (see Table 1). For the baseline, we set W_{AOM} and W_{BM} to 0.25 and 0.75, respectively, based on the guidance given in the CDM method. The crediting period for no-lose targets is set at year 2012-2020 and the year 2020 falls within the second and third crediting period of the CDM guidance. This assumption on the weightings is also in line with a study by (Kahrl and Roland-Holst, 2006) that estimated that more than 60 percent of China's 2020 generating capacity will be built during the period 2005-2020, i.e., new and recent generation capacity is judged to have a more significant effect on the national average carbon intensity in 2020 than older capacity and should therefore have a higher weighting factor.

For the dynamic crediting target, the factors W_{AOM} and W_{BM} might be negotiated at the international level, depending on the projection of the actual carbon intensity in 2020 and an expected share of total emissions reductions that are reduction credits. In this study, we follow the CDM guidance, which sets a change in the weighting factors W_{AOM} and W_{BM} by 0.25 every crediting period: 1) W_{AOM} and W_{BM} are set to 0 and 1, respectively, for countries with BM_{2005} lower than AOM_{2005} and 2) W_{AOM} and W_{BM} are set to 0.5 for countries with BM_{2005} higher than AOM_{2005}. This implies that the carbon intensity that would be realized after the third CDM crediting period (after 2026) should be realized in 2020 instead. Stated differently, these weightings imply that the existing electricity system is converted to the point where the electricity generation mix and the average efficiency of power plants in 2020 correspond to those of the build margin of 2005, for countries with BM_{2005} lower than AOM_{2005}.

As an alternative to the dynamic crediting target, we also use another type of crediting target, designated fixed crediting target, where the average carbon intensity is set constant during the period 2012-2020. For countries with BM_{2005} lower than AOM_{2005}, the fixed crediting target is set constant at the 2020 value of the national average carbon intensity of the baseline; $CM_{2020,\ baseline}$. For countries with BM_{2005} higher than AOM_{2005}, the fixed crediting target is set constant at the 2012 value of the national average carbon intensity of the baseline; $CM_{2012,\ baseline}$.

Table 1. Assumptions on the values of the national average carbon intensity in 2020 (CM_{2020}) of the baseline and crediting targets for each country

	CM_{2020} for countries with $BM_{2005} < AOM_{2005}$	CM_{2020} for countries with $BM_{2005} > AOM_{2005}$
Baseline	$0.25^* AOM_{2005}+0.75^* BM_{2005}$	
Dynamic target	BM_{2005}	$0.5^* AOM_{2005}+0.5^* BM_{2005}$
Fixed target	$0.25^* AOM_{2005}+0.75^* BM_{2005}$ (= $CM_{2020,\ baseline}$)	$CM_{2012,\ baseline}$

3.2 Scenario analysis

For calculating CO_2 emissions and the potential for emissions reduction and reduction credits in the electricity sector in the seven countries during 2012-2020, projections for 1) electricity generation growth and 2) average efficiency of fossil power plants and share of all fossil electricity (used for calculating the national average carbon intensity) (of ambitious scenarios) are made.

Electricity generation growth

From a base year of 2005, the annual average growth in electricity generation is set equal to the annual average growth during 2000-2005 in each country except for China, i.e., 3 percent in South Africa and Mexico, 4.5 percent in India, 6.5 percent in Thailand and Indonesia, and 8 percent in South Korea. For comparison, the reference scenario of World Energy Outlook has a 4.9 percent annual growth in India during 2004-2030 (WEO, 2006). For China, the annual average growth during 2000-2005 is estimated at 12.6 percent. However, we set the annual average growth from the base year 2005 to 6.5 percent based on the Chinese goal of quadrupling the country's 2000 GDP by 2020 (implying an annual average GDP growth rate of 6.5 percent from 2005-2020) and an electricity elasticity of 1 from 2005-2020 (Kahrl and Roland-Holst, 2006; Cai et al, 2007). Based on our assumption, the electricity generation in China in 2020 would be 6,420 TWh (see Figure 4), which is somewhat higher than a projection for electricity demand made by China Development Bank (Kahrl and Roland-Holst, 2006).

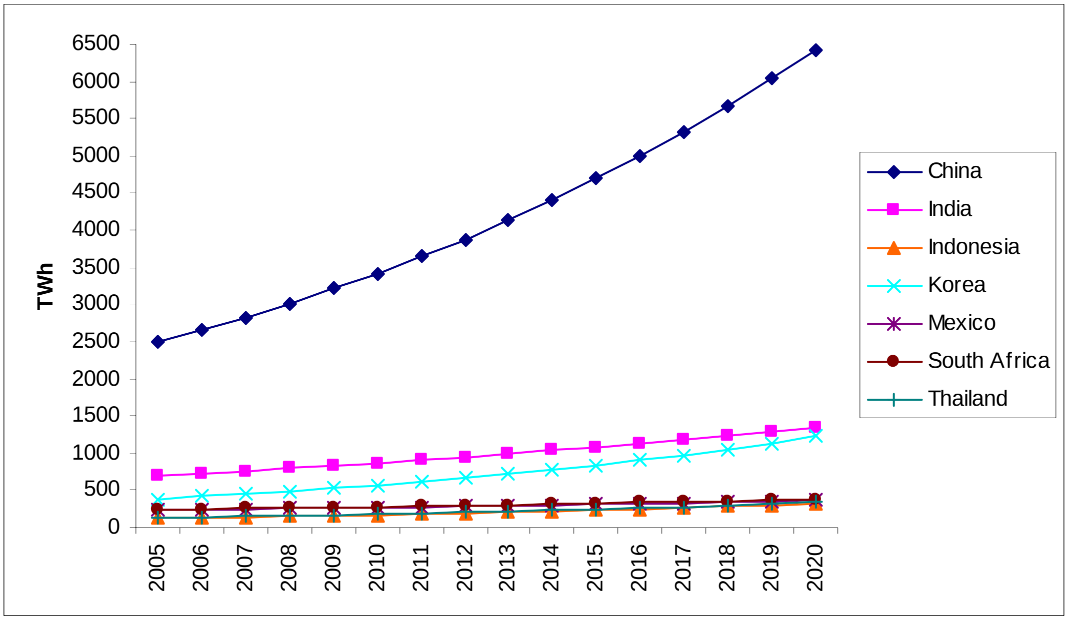

Figure 4. Projected electricity generation in seven countries from 2005-2020

Scenarios of average efficiency of fossil power plants and share of all fossil electricity

In order to reduce the CO_2 emissions to a level below the sectoral crediting targets, each country has the flexibility to reduce emissions with the most cost-effective options available domestically, including 1) switching to less carbon intensive fossil fuels in existing power plants and installing new plants that use less carbon intensive fuels; 2) increasing the average efficiency of fossil fuel power plants (through the installation of new high-efficient plants and/or upgrading existing plants); 3) increasing the share of renewables-based electricity or other CO_2-neutral electricity; 4) capturing and storing carbon from fossil fuel power plants.

In order to assess the total amount of emissions that could be reduced by the seven developing countries compared to the baselines during the period 2012-2020 and the amount of emissions reduction credits that could be generated based on the proposed targets, we define four scenarios;

Scenario 1: To increase the average efficiency of coal power plants, this scenario assumes that new coal power generation capacity would be on average 40 percent efficient (predominantly subcritical, fluidized bed, and supercritical coal power plants). The average efficiency of coal power plants in China in 2020 would in this scenario roughly correspond to the coal power plant efficiency goal for China in 2020 (38 percent).

Scenario 2: To increase the average efficiency of both coal and gas power plants, this scenario assumes Scenario 1 plus that new gas power generation capacity would be on average 50 percent efficient (efficient combined cycle plants). These two efficiency values are roughly an average of the efficiency values of the most-efficient and least-efficient of new (after 2000) widely available coal and gas-based power generation technologies given in (UNFCCC, 2007).

Scenario 3: To decrease the share of coal-based electricity, this scenario assumes that the average share of coal-based electricity in new generation during the period 2005-2020 decreases by 12 percent compared to that of the build margin of 2005. The decrease in the share of coal-based electricity is set to be balanced by carbon-neutral electricity. For China, this scenario implies that the average share of coal-based electricity in 2020 would be about 79 percent, the same as that of the average operating margin in 2005.

Scenario 4: To increase the average efficiency of both coal and gas power plants and decrease in the share of coal-based electricity in the new generation, this scenario assumes a combination of Scenario 2 and 3.

For all the scenarios, we use a linear change of the electricity generation mix and average efficiency of fossil power plants from 2005 to 2020. The values of the generation mix and average efficiency of fossil power plants in 2020 for each country are based on a weighted average of the values of the existing plants in 2005 and the average values of new power plants during 2005-2020. The weighting factors for the existing plants and new plants are set to 0.25 and 0.75, respectively.

Table 2. Assumptions on the values of the average efficiency of different fossil power plants and the average share of different fossil electricity in new power plants added over the period 2005-2020 for each country

	Average efficiency of fossil power plants	Average share of fossil electricity
Scenario 1	Coal (40%), Gas (BM*), Oil (AOM*)	Coal, Gas and Oil (BM*)
Scenario 2	Coal (40%), Gas (50%), Oil (AOM*)	Coal, Gas and Oil (BM*)
Scenario 3	Coal (BM*), Gas (BM*), Oil (AOM*)	Coal (88% of BM*), Gas and Oil (BM*)
Scenario 4	Coal (40%), Gas (50%), Oil (AOM*)	Coal (88% of BM*), Gas and Oil (BM*)

BM* = the percent value corresponding to the build margin in 2005 (see Table 3)
AOM* = the percent value corresponding to the average operating margin in 2005 (see Table 3)

The following formulae illustrate how CO_2 emissions in the electricity sector and CO_2 emission reduction credits from each country are calculated for the baseline, crediting targets, and Scenario 1-4:

$$CE_{y,s} = EG_{2005} * (1+AEG/100)^{(y-2005)} * AOM_{y,s}$$

Where:

$CE_{y,s}$ = CO_2 emissions from electricity generation in year y for scenario s
EG_{2005} = Total electricity generation in 2005 (kWh)
AEG = Annual average increase rate of electricity generation (%)
$AOM_{y,s}$ = National average carbon intensity in year y (gCO_2/kWh) for scenario s
s = Scenario (baseline, dynamic crediting target, fixed crediting target, or Scenario 1-4)

The total emissions reduction (ER) in year y:

$ER_y = CE_{y,\ baseline} - CE_{y,\ scenario}$

The CO_2 emission reduction credits (CER) in year y during the crediting period (2012-2020) is calculated as follows:

$CER_y = CE_{y,\ crediting\ target} - CE_{y,\ scenario}$

The above formulae show that the amount of CO2 emission reduction credits depends on electricity generation growth. If the electricity generation is judged to grow too fast and lead to strong growth of CO_2 emissions, the amount of reduction credits could be subtracted by a factor to discourage growth of electricity demand and generation. This could be done by setting a target on CO_2 emissions from electricity generation per capita such as a target of 3 tCO_2/capita. If in any year during 2012-2020, the CO_2 emissions from electricity generation per capita exceed this per capita target, the net reduction credits would be the CO_2 emission reduction credits from the above formula subtracted by the multiplication of the difference between per capita exceeded emissions and per capita emissions target with the number of population in that specific year. Countries would get credits at the amount of net reduction credits only if these net credits are positive. However, we have not included this per capita target in the above formula.

A sensitivity analysis is made for the Chinese electricity generation growth rate for scenario 4 where two scenario variants are tested; 1) a high growth rate scenario having 8.5% electricity growth per year, i.e., 30 percent higher annual average electricity generation growth than the 6.5% in scenario 4; and 2) a low growth rate scenario having 4.5%/year electricity growth per year, i.e., 30 percent lower than in scenario 4..

3.3 Data

National data on $C_{TOT,\ 2005}$ and $E_{TOT,\ 2005}$ for calculating the average operating margin in 2005 (AOM_{2005}) are taken from IEA energy balances (IEA, 2007). $C_{TOT,\ 2005}$ is calculated based on the sum of the multiplication of total fossil fuel inputs (coal, oil and gas) consumed for power generation of all power plants serving the grid in 2005 with their corresponding emission factors (coal 94.6 gCO_2/MJ, oil 77 gCO_2/MJ and natural gas 56.1 gCO_2/MJ) based on (IPCC, 1996).

The values of the build margin emission factor for all the seven countries are taken from the Project Design Document (PDD) of CDM projects that supply electricity to the grid (UNFCCC, 2008a-g). The 2005 build margin value for China is the average value of the build margins of seven regional grids in China and is weighed by additional generation in 2005 in each region. Electricity generation mixes and average efficiency of fossil power plants that correspond to the operating and build margin carbon intensity in each country are based on our own calculation and data from (IEA, 2007) and (UNFCCC, 2008a-g) and are presented in Table 2.

Table 2. Average operating margin (OM) and build margin (BM) carbon intensity of six countries of 2005 and of Indonesia of 2006 and the corresponding generation mix and average efficiency of fossil power plants

Country	Carbon intensity ($kgCO_2/kWh$)		Electricity generation mix (% of total electricity generation MWh)						Fossil power plants efficiency[2] (%)		
			Coal	Oil	Gas	Hydro	RE[1]	Nuclear	Coal	Oil	Gas
China	OM	0.86	79.0	2.4	0.5	15.9	0.1	2.1	32.1	34.6	38.9
	BM	0.79	90.4	0	1.0	8.2	1.0	0.01	(37.3)	-	(48.8)
India	OM	0.97	68.7	4.5	8.9	14.3	1.2	2.5	26.5	32.7	41.9
	BM	0.68	59.1	1.0	14.2	4.9	0.0	20.7	(33.0)	NA	(44.0)
Indonesia	OM	0.74	42.9	33.7	14.5	8.9	0	0	34.0	37.9	42.6
	BM	0.94	88.1	5.8	2.7	0	3.3	0	(35.8)	NA	NA
Korea	OM	0.44	38.5	6.3	16.1	1.0	0.1	38.0	38.7	50.6	48.8
	BM	0.37	27.6	0	29.6	0	0.1	42.7	(37.8)	-	48.2
Mexico	OM	0.53	14.5	30.2	37.2	12.2	1.1	4.7	39.8	37.8	40.6
	BM	0.37	0	0.3	87.3	12.3	0	0	-	NA	(50.0)
Thailand	OM	0.54	15.1	6.6	71.4	4.4	2.5	0	36.4	37.8	42.7
	BM	0.45	0.1	3.4	89.7	1.4	5.4	0	(37.4)	(40.0)	(44.0)
South Africa	OM	0.94	94.1	0	0	0.9	0.3	4.6	33.9	-	-
	BM	1.05	100	0	0	0	0	0	(33.2)	-	-

[1] RE is an abbreviation for renewable-based electricity
[2] The numbers in bracket are approximate values and are taken from project design documents (PDDs) or from our own calculation based on data available in the PDDs
NA (not available)

4. Results

Five countries have a downward baseline and dynamic target. Indonesia and South Africa are exceptions where BM_{2005} has a higher value than AOM_{2005} and the share of coal-based electricity is expected to increase from 2006-2020 (Figure 5). In scenario 4, designated "ambitious" in Figure 5, the national average carbon intensity in 2020 would decrease compared to that in 2005 by: 37 percent in India; 23 percent in Mexico; 21 percent in Thailand; 20 percent in Korea; 16 percent in South Africa; 15 percent in China; and 2 percent in Indonesia..

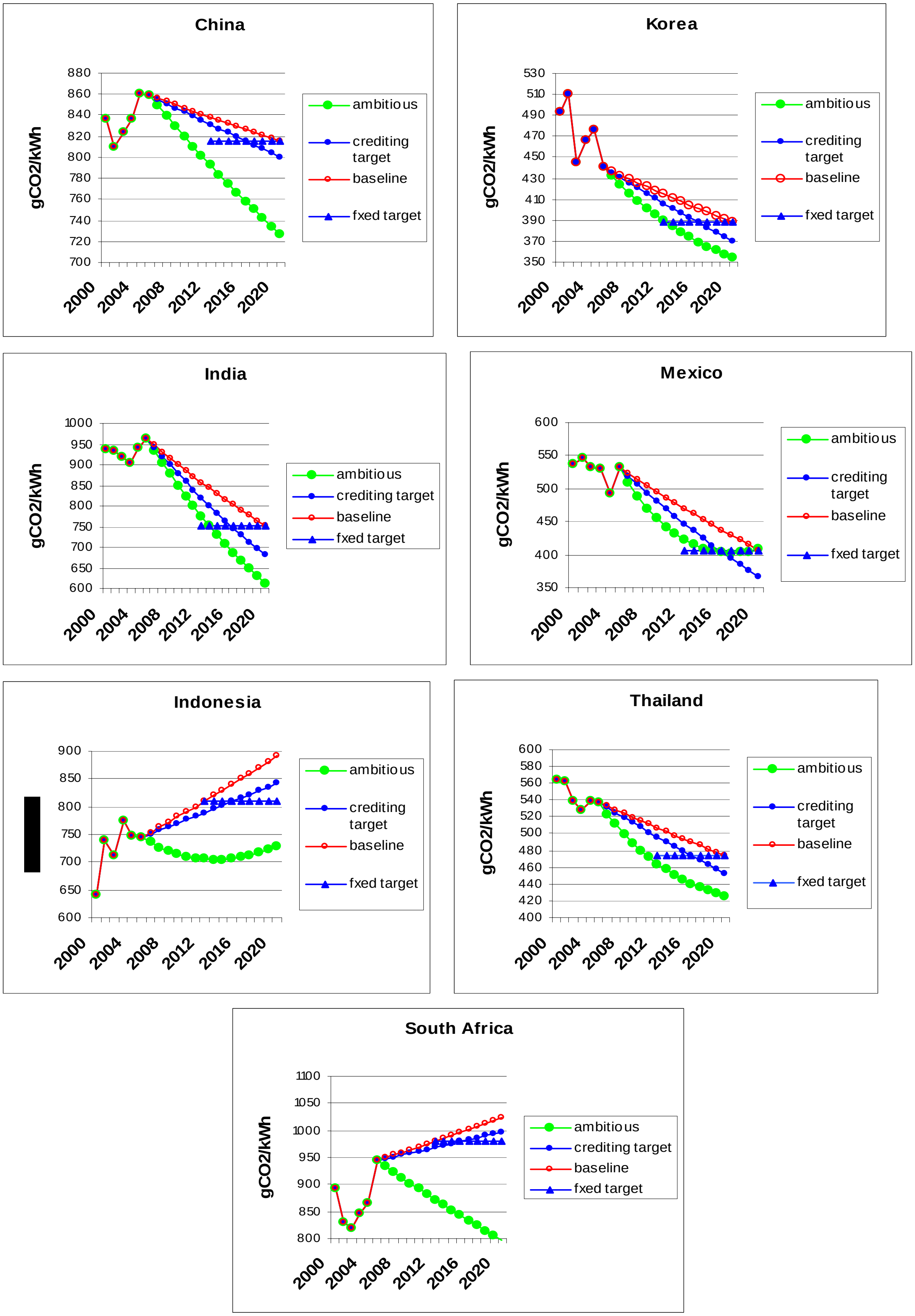

Figure 5. Historical national average carbon intensity in the electricity sectors in the seven studied countries from 2000-2005. Also shown are the projected national average carbon intensities 2006-2020 for the baseline; crediting targets; and scenario 4.

The total CO_2 emissions from electricity generation in all seven countries in the baseline scenario are expected to more than double from 3,520 Mt in 2005 to 7,700 Mt in 2020 (Figure 6). The total annual average emissions reduction during 2012-2020 would range from 230 $MtCO_2$/yr of Scenario 1 to 630 $MtCO_2$/yr of Scenario 4, corresponding to 3.7 to 10.1 percent of the total annual average emissions, respectively (Table 4). As can be seen in Table 4, the decrease in the share of coal-based electricity by 12 percent in Scenario 3 would lead to a larger amount of annual average emissions reduction than the increase in the average efficiency of both coal and gas-based power plants in Scenario 2. Also, the increase in the efficiency of gas-based power plants in Scenario 2 would lead to less emissions reduction than the increase in the efficiency of coal-based power plants in Scenario 1.

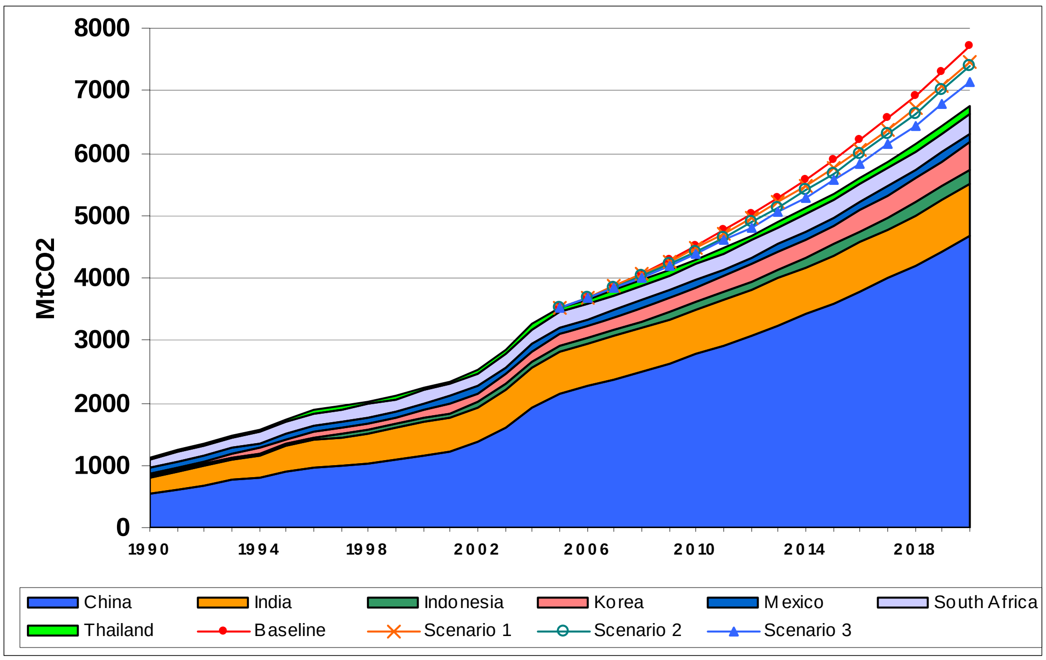

Figure 6. Historical CO_2 emissions from 1990-2005 and projected CO_2 emissions in the ambitious scenario 4 from 2006-2020 from electricity generation in seven countries (all colored area), compared with the baseline scenario (upper line) and the ambitious scenario 1, 2 and 3 (middle lines)

Table 4. Total emissions in 2020, annual average emissions reduction and reduction credits during 2012-2020 of Scenarios 1-4 (S.1-S.4)

	Unit	S.1	S.2	S.3	S.4	S.4 (4.5%/year)*	S.4 (8.5%/year)*
Total emissions in 2020	$MtCO_2$	7405	7381	7133	6760	5631	8219
Annual average reduction	$MtCO_2$/ year	230	245	395	630	562	718
Share of total reduction to total emissions	%	3.7	3.9	6.3	10.1	10.2	9.9
Annual average reduction credits (dynamic target)	$MtCO_2$/ year	71	84	239	470	411	541
Share of total credits to total reduction (dynamic target)	%	31	34	61	74	73	75
Annual average reduction credits (fixed target)	$MtCO_2$/ year	110	123	263	484	423	560
Share of total credits to total reduction (fixed target)	%	48	50	67	77	75	78

* indicates the annual average growth of power generation in China

The total annual average emissions reduction credits for scenario 4 would amount to 470 and 484 Mt/year, based on the dynamic and fixed target, respectively, corresponding to approximately 75 percent of the annual emissions reduction (Figure 7). Expressed as share of the total reduction, the total annual reduction credits is largest for the fixed target, with the smallest difference between fixed and dynamic target in Scenario 4. Of the total annual average credits, China would earn about 60 percent in Scenario 4, India 15 percent, South Africa 10 percent, Indonesia and South Korea about 5 percent, Thailand 2 percent, and Mexico would earn less than 1 percent (based on both dynamic and fixed crediting targets). Quite different from scenario 1, 2 and 3, the share of the total annual average credits among countries during 2012-2020 in scenario 4 is roughly proportional to the share of total projected annual electricity generation among countries[1] and also the share of total annual average reduction among countries[2] (Figure 7).

[1] 60 percent from China, 15 percent from India, 10 percent from Korea, 5 percent from South Africa, and 3 percent from Mexico, Indonesia and Thailand.
[2] 55 percent from China, 20 percent from India, 10 percent from South Africa, 5 percent from Korea and Indonesia, 2 percent from Thailand, and 1 percent from Mexico.

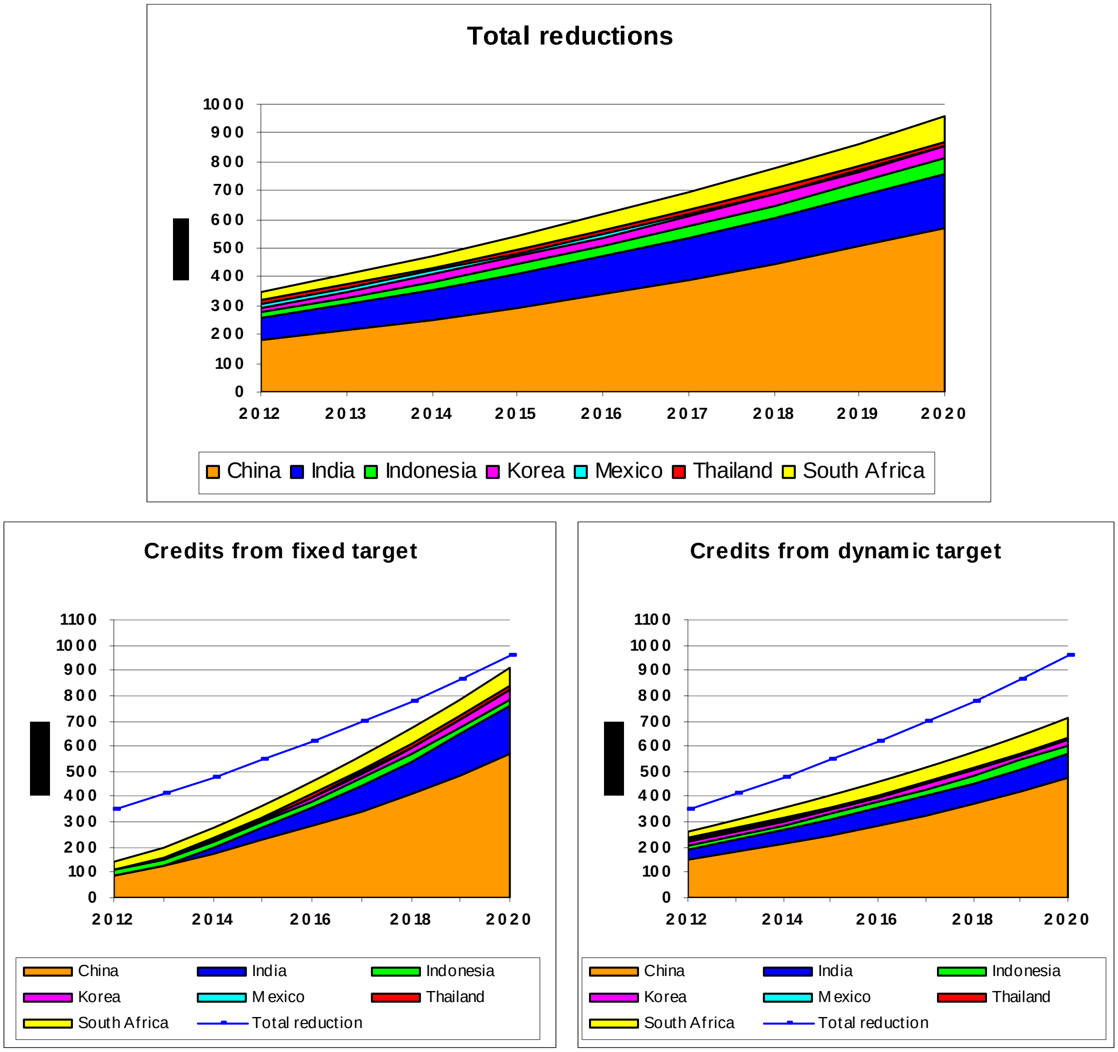

Figure 7. Total emissions reduction and emission reduction credits (Mt CO2) in Scenario 4

Assuming a 30 percent lower and higher annual average electricity generation growth in China, compared with the reference, the total CO_2 emissions from electricity generation from all seven countries in the baseline scenario increase from 3,520 Mt in 2005 to 5,630 and 8,220 Mt in 2020, respectively. The total annual average emissions reduction during 2012-2020 in scenario 4 would range from 560 to 720 Mt/year, respectively, and the share of the total annual average emissions reduction would remain at about 10 percent of the total annual emissions (Table 4). In addition, the relative size of the total annual average emissions reduction credit compared to the total annual average emissions reduction would remain roughly unchanged for both the dynamic and the fixed crediting target. With a 30 percent increase in the annual average electricity generation growth, China's share in the total annual credits would increase by about 5 percent. The share of the total annual credits for the other countries would become 1-2 percent lower.

5. Concluding remarks and policy implications

The proposed baseline and targets build upon an existing method developed for calculating baseline emissions for a CDM project activity that supplies electricity to the grid. The baselines and crediting targets take into account different country characteristics (i.e., different electricity generation mix and average efficiency of power plants in the electricity system in each developing country). The proposed baselines and targets could be applied for any developing countries who want to voluntarily participate in reducing emissions through the sectoral no-lose targets for electricity sector.

As has been reported above, a significant reduction of CO_2 emissions could be acheived in the electricity sector by increasing the average efficiency of coal and gas power plants and by decreasing the share of coal-based electricity. The total emissions could be reduced by the seven countries by 10 percent compared to the baseline by 2020, if (i) new coal and gas-based power plants added from 2005-2020 is on average 40 and 50 percent efficient, respectively, and (ii) the average share of coal-based electricity from new generation capacity decreases 12 percent compared to that of the build margin of 2005. To achieve the same level of the emissions reduction, these countries have some flexibility to reduce emissions with the most cost-effective options available in each country.

Substantial volumes of annual credits would become generated given the proposed crediting targets (some hundred million tons of CO_2 per year) and could provide substantial incentives for developing countries to make a significant reduction of emissions in the electricity sector. If all seven countries achieve the Scenario 4, most of the total credits would be generated in China, and the share of the total credits for each country would be rather proportional to the share of the total reductions and the share of total electricity generation. Each country's government could assign the amount of generated credits to each relevant stakeholder (i.e., each power plant developer) that contributes to reducing the national average carbon intensity based on own policy or based on applications of the current methodologies for calculating project-based emissions reduction credits of the CDM.

The types of targets proposed (dynamic versus fixed targets) do not significantly affect the share of the total credits related to the total emissions reduction when all seven countries achieve the scenario 4. More equal amounts of credits would be generated for the dynamic target, while a larger amount of credits would be generated at the end of crediting period for the fixed target.

The absolute amount of emissions, emissions reduction and credits are very sensitive to the electricity generation growth. However, the share of emissions reduction to total emissions and the share of credits to total reduction are not very sensitive to the electricity generation growth.

The results imply that substantial efforts from both private sectors and governments in these countries are needed to make radical emission reductions in the electricity sector. The current project-based CDM has so far helped to reduce the electricity sector emissions mainly by boosting private sectors' development of renewables power projects (mainly hydro, wind and biomass power projects) and natural gas power projects. The most recent development in the CDM is the entry of significant numbers of large-hydro and natural gas power projects in the CDM project pipeline. However, these projects lack credibility regarding their environmental integrity objectives (i.e., whether the projects would have been implemented in the absence of the CDM is questionable) (Wara M., 2008). The sectoral crediting target could provide substantial incentives to stimulate a sector-wide structural change in the electricity sector and could influence the government plan and policy for new power generation capacity to become more efficient and less carbon intensive. This sectoral approach could also encourage systematic data collection and monitoring of electricity generation and fuel consumption in the electricity sector in developing countries.

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