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A clear signal to power generation companies and utilities planning new power plants in developing countries post-2012

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Electricity sector crediting mechanism based on a power plant emission standard: A clear signal to power generation companies and utilities planning new power plants in developing countries post-2012

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Abstract

This article proposes and investigates a project-based crediting mechanism which is based on a national CO_2 emission intensity standard for new power plants to be added in the electricity sector from 2013-2020 in developing countries. Under this mechanism, the power plant emission intensity standard (gCO_2/kWh) is used as the basis for issuing credits for new power plants with an emission intensity below the standard and also for imposing taxes on new power plants with an emission intensity above the standard. The mechanism is based on mechanisms that have been proposed or already been implemented, including sectoral no-lose target, sectoral CDM, environmental performance standard and carbon tax. Any developing countries could voluntarily participate in this mechanism. If countries participate in gaining credits from this mechanism, the government of the countries would be required to either regulate/prohibit new plants or impose taxes on new plants with an emission intensity above the standard.

In this article, an approach for setting the power plant emission intensity standard is developed based on the combined margin approach used for setting baseline emissions factor for CDM power projects. The power plant emission standard is set to correspond to a sectoral target which is set below the business-as-usual intensity level in the electricity generation sector. The standard is set for seven developing countries with large amount of CO_2 emissions from electricity generation. The potential volume of emissions reduction, number of credits generated and volume of emissions taxed ($MtCO_2$) are also assessed for the seven countries by means of different scenarios.

The assessment shows that this mechanism could send a clear signal (through both credits and taxes) directly to all major power generation companies and utilities planning to build new power plants and thus ensure that the overall performance of the power sector would be significantly improved. The mechanism could lead to a participation of both the government and the private sector in reducing emissions in each country. The assessment also shows that setting the power plant standard below the business-as-usual emissions intensity level and excluding some types of projects that are common in each country from gaining credits could help improve and ensure the environmental integrity of the mechanism. A significant reduction of CO_2 emissions could be achieved in the sector by decreasing the share of coal-based electricity and boosting the efficiency of coal power plants in new generation capacity during 2013–2020 in the seven countries. Given the set power plant standard, substantial volume of credits would be generated.

Keywords: emissions intensity standard, power plant, electricity sector, developing countries, post-2012
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1. Introduction

In international negotiations on a future climate regime, sectoral approaches are proposed as a way to scale-up emissions reduction in developing countries. Many proposals focus on the introduction of new sectoral carbon market mechanisms. These include 1) a sectoral CDM which is a project-based crediting mechanism that applies the crediting baseline set at the sector level (sectoral baseline) and usually set at the business-as-usual (BAU) emissions or emissions intensity level and 2) a sectoral crediting mechanism (SCM) based on sectoral no-lose targets which is a sector-based crediting mechanism that applies the crediting baseline set at the sector level (sectoral target) and set below the BAU level (i.e., below the sectoral baseline) (Schneider and Cames, 2009).

There are several implementation issues that need to be resolved in order for these two mechanisms to achieve the goal of a scale-up emissions reduction. Under the sectoral CDM, incentives (i.e., credits) are provided directly to individual projects based on the performance of each project, but it is not clear how the mechanism would ensure that the overall emission performance of the sector would be significantly improved.

On the other hand, under the SCM, credits are issued to the government in the first instance based on the overall performance of the whole sector (all entities/activities included in the sector) to ensure that the overall performance of the sector would be improved. However, if the overall performance of the sector has to be assessed and improved before issuing credits to the government, there may be no incentive for the private sector to invest in reducing their emissions. Several approaches for resolving this issue under the SCM have recently been discussed in (Baron et. al, 2009; Schneider and Cames, 2009). However, it implies that the success of implementing this mechanism relies heavily on the government. In addition, it is not clear how to ensure that the government in each country would provide a clear incentive to encourage private sector (project developers) to reduce their emissions so that the overall performance of the sector is significantly improved. Besides, if the credits are reissued directly from the government to the private sector, not based on the project performance (i.e., not project-based crediting), it is not clear on what basis the credits would be given to the project developers to encourage them to contribute to the improvement of the overall performance of the sector.

Stated differently, if an overall goal of these mechanisms is to make a significant scale-up of reductions occur in a sector, a clear signal is needed to be sent to all major project developers/entities in the sector to participate in reducing their emissions. It is not clear how these two mechanisms would send a clear signal to stimulate all these major project developers/entities in the sector to participate in reducing their emissions so that the overall performance of the sector is improved at a significant level. For example, in the power sector, a clear signal is needed to be sent to power generation companies and utilities developing *new fossil fuel power plants*. Rubin, 2009 discussed about a CO_2 performance standard as an approach for sending a clear signal to those developing new fossil fuel power plants to reduce CO_2 emissions in the U.S power sector. CO_2 tax implemented in a few countries such as Norway and Sweden could also send a clear signal to those developing fossil fuel power plants.

Ensuring the environmental integrity of the two mechanisms is another challenging implementation issue and has been mentioned in (Schneider and Cames, 2009; Baron et. al, 2009). Approaches for improving the environmental integrity of the current CDM (e.g., negative-positive lists and discounting of certified emissions reduction) are proposed and discussed in (Schneider and Cames, 2009; Baron et. al, 2009). However, no specific approaches are proposed to ensure the environmental integrity of the sectoral CDM and SCM (i.e., ensure that emissions reductions are additional either at the project level or at the sector level and ensure that the total number of credits ($MtonCO_2$) generated from these mechanisms does not exceed the total volume of actual emissions reductions ($MtonCO_2$) at the sector level, if credits are to be used as offsets as in the CDM). Stated differently, it is not clear how the two mechanisms will ensure that only projects/activities that lead to additional emissions reduction are credited and how to set a sectoral baseline and a sectoral crediting baseline used as the basis for issuing credits that are conservative or ambitious.

Several approaches for setting the sectoral crediting baseline for the SCM are discussed in (Schneider and Cames, 2009). A sectoral baseline is not suggested to be set based entirely on a political basis (Baron et al., 2009).

Setting a sectoral baseline and a sectoral crediting baseline in developing countries based entirely on political basis or on proposals from developing countries and negotiations may not lead to a conservative or ambitious baseline, since there may be no incentive for developing countries to set an ambitious baseline which would generate a smaller number of credits. In the electricity generation sector, Amatayakul et al. 2008 and Amatayakul et al. 2009 proposed to use the combined margin approach which is an objective approach currently used in the CDM methodology as one basis for setting the sectoral baseline and sectoral crediting baseline.

To overcome some of the mentioned key implementation issues, a mechanism that combines the strength of the sectoral CDM (i.e., sending a clear signal to the private sector and providing incentives based on the project performance) and the SCM (i.e., setting a sectoral crediting baseline below the BAU level to ensure the environmental integrity and paying attention to the improvement of the overall performance of the whole sector) and that also sends a clear signal to *all* major project developers in the sector may be needed.

The aim of this article is to propose and investigate a project-based crediting mechanism which is based on a national emissions intensity standard for new power plants to be added in the electricity sector from 2013-2020 in developing countries. Under this mechanism, the power plant emissions intensity standard (gCO_2/kWh) is used as the basis for issuing credits for new power plants with an emission intensity below the standard and also for imposing taxes on new power plants with an emission intensity above the standard. This mechanism is based on mechanisms that have been proposed or already been implemented, including the sectoral no-lose target, the sectoral CDM, and the emissions performance standard and carbon tax. This article also aims to give a clearer picture of how a crediting mechanism might be implemented based on an electricity sector no-lose target as presented earlier in (Amatayakul et. al, 2008).

In this article, an approach for setting the standard for new power plants added during 2013-2020 is developed. The standard is set for seven developing countries with large amount of carbon dioxide (CO_2) emissions from electricity generation. The potential volume of emissions reduction, the potential number of credits generated, and the potential volume of emissions taxed ($MtCO_2$) are also assessed for the seven countries by means of different scenarios.

The top ten developing countries with largest amount of CO_2 emissions from electricity generation in 2005 (in order of the magnitude of emissions) are China, India, South Africa, South Korea, Saudi Arabia, Mexico, Iran, Indonesia, Kazakhstan and Thailand (IEA, 2007). Based on this historical data, seven countries where relevant data are currently available are chosen for this analysis including China, India, Indonesia, Mexico, South Korea, South Africa and Thailand.

The article is structured as follows. Section 2 reviews crediting CDM projects in the electricity generation sector in the seven developing countries. Section 3 outlines the methodology and data used. Section 4 discusses the results. Section 5 presents the concluding remarks and policy implications.

2. Review of crediting CDM power generation projects in the seven developing countries

Under the CDM, power generation projects that supply electricity to the national grid are issued credits against a baseline emissions factor. This baseline emissions factor is set for each project (i.e., project baseline emissions factor). This baseline emission factor is set based on the combined margin approach, or the emission factor of the technology and fuel identified as the most likely baseline scenario, or a benchmark emission factor determined based on the performance of the top 15 per cent power plants that use the same fuel as the project and any technology available in a geographical area. Details of these approaches are summarized in Table 1.

Table 1. Major methodologies for setting the baseline emissions factor for CDM power generation projects that substitute electricity from the grid (UNFCCC, 2009)

Major CDM methodologies	Types of projects applicable	How the baseline emissions factor value is set**
Tool to calculate the emission factor for an electricity system, used for -ACM002 (Grid-connected electricity generation for renewable sources excluding biomass) -ACM006 (Grid connected electricity from biomass residues) -AMS.I.D (Small-scale renewable electricity generation for a grid)	All renewable energy power generation plants	For wind and solar power projects: 0.75*OM+0.25*BM for the first and subsequent crediting periods For all other projects: 0.5*OM+0.5*BM for the first crediting period 0.25*OM+0.75*BM for the second and third crediting period
AM0029: Baseline methodology for grid-connected electricity generation plants using natural gas	New natural gas fired power generation plants	The lowest emission factor value of the following three options: 1. BM 2. 0.5*OM+0.5*BM 3. The emission factor of the technology (and fuel) identified as the most likely baseline scenario
ACM0013: Consolidated baseline methodology for new grid connected fossil fuel fired power plants using a less GHG intensive technology	High-efficiency fossil fired power generation plants (e.g., supercritical coal-fired plants)	The lower emission factor value of the following options: 1. The emission factor of the technology and fuel type identified as the most likely baseline scenario 2. A benchmark emission factor determined based on the performance of the top 15% power plants that use the same fuel as the project and any technology available in a geographical area

**Operating margin (OM) emission factor is the average emissions intensity of existing power plants (a 3-year generation-weighted average of the operating margin emissions factor in the three most recent years is used)

**Build margin (BM) emission factor is the average emissions intensity of either the most recent capacity additions, comprising 20 per cent of the total generation, or five power plants that have been built most recently –whichever comprises the larger generation

Under the combined margin approach, the baseline CO_2 emissions factor 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. The operating margin and build margin emission factors are based on either the national grid or a regional grid in the country and are set based on a base year. Table 2 shows that in many cases the baseline emissions factor for a CDM project in a country varies substantially between different project types and within the project types. Several base years are also used to set the baseline emissions factors. It also shows that the generation-weighted average emissions factor of all types of power generation projects in each country has at a higher value than the value of the build margin emissions factor based on 2005 (see Table 2, column all types and BM_{2005}).

Table 2. Generation-weighted average baseline emissions factor ($kgCO_2/kWh$) used for estimating emissions reduction credits in 2012 for registered CDM grid-connected power generation projects of different types (the values in brackets are the minimum and maximum values) compared with average operating margin and build margin emissions intensity of seven countries based on 2005

	Gas	Coal*	Wind	Hydro	Biomass	All types**	AOM_{2005}	BM_{2005}#
China	0.80 (0.57-0.91)	0.87 (0.86-0.88)	1.02 (0.74-1.15)	0.88 (0.63-0.98)	0.95 (0.86-1.03)	0.87	0.86	0.80
India	0.74 (0.63-0.78)	1.02 (0.94-1.11)	0.95 (0.42-1.12)	0.85 (0.66-1.07)	0.84 (0.62-1.02)	0.96 (0.83***)	0.96	0.68
Indonesia	-	-	-	-	0.73 (0.66-0.8)	0.73	0.74	0.94
South Korea	-	-	0.63 (0.61-0.73)	0.57 (0.55-0.63)	-	0.62	0.46	0.37
Mexico	-	-	0.61 (0.55-0.98)	0.54 (0.53-0.55)	-	0.61	0.55	0.37
Thailand	-	-	-	-	0.51 (0.51-0.54)	0.51	0.54	0.45
South Africa	-	-	-	-	-	-	0.95	1.04

*CDM coal power plant projects that have not been registered
** All types include gas, coal, wind, hydro and biomass power projects
***the value if excluding coal
for Indonesia, based on 2006

Common for China and India is that a major share of the total generation from these projects in 2012 is expected to be from fossil fuel power plants (i.e., coal and gas power plants) (Table 3). Stated differently, these countries continue to rely on fossil fuels for power generation. If coal power projects that are not registered are included for consideration, about 70 per cent of the total electricity generation from these projects in 2012 in the seven countries is expected to be from fossil fuel power plants in China and India (i.e., coal and gas power plants). A significant share of the total generation is also expected to be from hydro power projects in China.

Moreover, the total generation from all these projects in the seven countries would constitute a small share of the total generation needed to be added in 2012 in these countries. The total generation from all these projects in China including the coal power projects accounts for less than 10 per cent of the generation needed to be added in 2012 (about 1,400 TWh need to be added if the annual average electricity generation growth is assumed at 6.5 per cent). Furthermore, Table 3 shows that there is no generation expected from renewable power projects in South Africa where 90 per cent of the total generation in 2005 was based on coal (IEA, 2007).

Table 3. Average generation capacity (MW), the number and the total generation (TWh) expected in 2012 of registered CDM grid-connected power generation projects as of May 1, 2009 of different types (the values in brackets are the minimum and maximum values)

	Unit	Gas	Coal*	Wind	Hydro	Biomass	Total
China	MW	828 (300-1528)	2250 (2000-3000)	51 (9-300)	31 (4-240)	24 (15-30)	
	Projects	11	4	120	248	11	394
	TWh	36.3	39.4	13.9	29.7	1.4	120.8
India	MW	332 (20-1148)	2650 (1320-4000)	24 (1-468)	18 (2-192)	10 (1-36)	
	Projects	5	4	75	49	114	247
	TWh	12.8	74.8	14.2	3.4	5.0	110.2
Indonesia	MW	-	-	-	-	10	
	Projects					2	2
	TWh					0.1	0.1
South Korea	MW	-	-	43 (3-98)	4 (1-8)	-	
	Projects			5	5		10
	TWh			0.6	0.1		0.7
Mexico	MW	-	-	160 (83-249)	17 (8-30)	-	
	Projects			7	3		10
	TWh			3.8	0.2		4.0
Thailand	MW	-	-	-	-	28 (9-41)	
	Projects					5	5
	TWh					0.6	0.6
South Africa	MW	-	-	-	-	-	-

The total number of emissions reduction credits expected in 2012 from all these projects in the seven countries amounts to about 70 $MtCO_2$. Figure 1 shows that a major share of the total number of emissions reduction credits in the seven countries generated is expected to be from China and from hydro power projects. If the number of emissions reduction credits is calculated against the build margin emissions factor based on 2005 in each country and is issued for all the power generation projects that are both registered and rejected (i.e., including non-additional projects), a smaller number of credits would still be generated in 2012 than the number of credits generated against the baseline emission factor for each project.

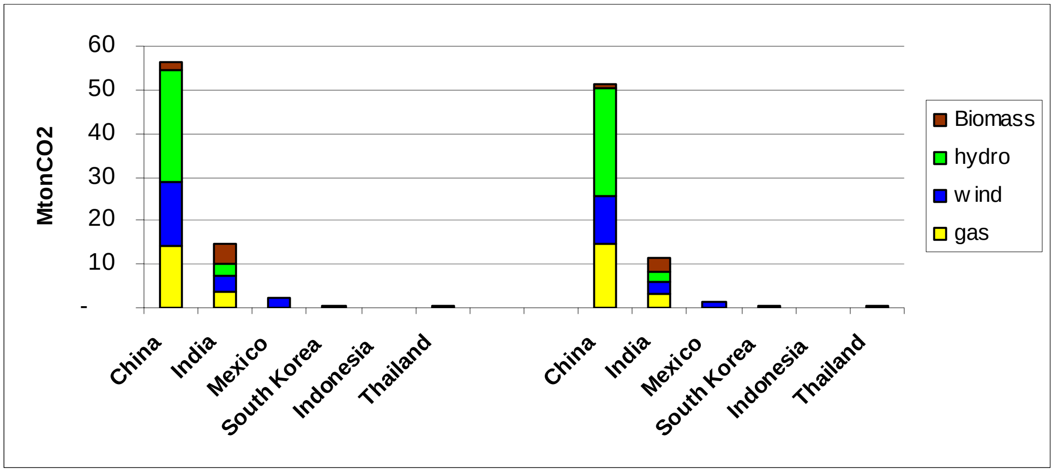

Figure 1. The number of emissions reduction credits ($MtCO_2$) expected to be generated in 2012 by registered CDM power projects as of May 1, 2009 in the seven developing countries based on the project baseline emissions factors (left graphs) compared with the number of credits expected to be generated by both registered and rejected projects based on the build margin emissions intensity based on 2005 in each country (right graphs) (Data are compiled from Fenhann, 2009 and IGES, 2009)

3. Methodology and data

3.1 Setting the national emissions intensity standard for new power generation projects (new power plants and capacity expansion plants)

In this article, the combined margin approach currently used for estimating the baseline emissions factor for crediting the displacement of grid-connected electricity generation by CDM power projects is used as the basis for setting a sectoral baseline and a sectoral target which is used for setting the power plant emissions intensity standard.

Using 2005 (the most recent year where data are available) as the base year, the combined margin emissions intensity in a crediting period is estimated as follows:

$CM = OM_{2005} * W_{OM} + BM_{2005} * W_{BM}$

Where;

OM_{2005} = Operating margin emissions factor ($kgCO_2/kWh$) based on 2005

W_{OM} = Weighting of operating margin emissions factor (per cent)

BM_{2005} = Build margin emissions factor ($kgCO_2/kWh$) based on 2005

W_{BM} = Weighting of build margin emissions factor (per cent)

The operating margin (OM) emission factor is generally defined as the average emissions intensity of existing power plants. There are a few different definitions of the operating margin emissions factor. If all power plants serving the national electricity grid are included, this is called the average operating margin (AOM) emissions factor. If all power plants serving the grid except low-cost and must-run power plants are included, this is called the simple operating margin (SOM) emissions factor.

If the combined margin approach is to be used for setting a national sectoral baseline, the average operating margin and build margin emissions factors need to be used, because the overall average emissions intensity of all existing power plants serving the grid and new power plants in the whole sector is considered. The values of the average operating margin and build margin emissions intensity of the seven countries are shown in Table 2.

The value of the combined margin emissions intensity is set based on the fact that the emissions intensity in the national grid in the future depends on the emissions intensity of both existing power plants and new power plants. Thus, the values of W_{OM} and W_{BM} need to be set to correspond to the shares of electricity generation from existing plants and from new plants in relation to total generation, respectively. The sum of these shares is equal to one. The value of AOM_{2005} represents the average emissions intensity of existing plants up to 2005, while the value of BM_{2005} represents the average emissions intensity of new plants added from 2006 to a future year.

In fact, the share of electricity generation from new capacity in the total future generation – W_{BM} – depends on the number of years away from a base year and electricity generation growth (Amatayakul et al, 2009). A higher growth rate and the larger number of years away from the base year would result in a larger share of electricity generation from new capacity.

If changes in the electricity generation of existing plants installed up to 2005 (e.g. through upgrading or shutting down of existing plants) are relatively insignificant over the period 2013–2020, the share of electricity generation from new capacity (compared to year 2005) in relation to total generation in year *y* can be calculated as follows:

$$ShareEG_{NEW,y} = 1 - \frac{1}{(1+\frac{r}{100})^{y-2005}}$$

Where:

$ShareEG_{NEW,y}$ = Share of electricity generation from new capacity in relation to total generation in year *y*

r = annual average electricity generation growth rate during 2005-year *y* (%/year)

The values of this share at different annual average electricity generation growth rates are presented in Table 4.

In this article, first, a sectoral baseline is set at the value of the combined margin emissions intensity in 2020, based on the assumption that the annual average electricity generation growth in each country is 10 per cent (i.e., W_{BM} = 0.75 and W_{AOM} = 0.25). The sectoral target at the same annual average generation growth is set in the same way as the baseline but with different values of the weighting factors.

The difference between the values of the weighting factors of the baseline and those of the target indicates the level of deviation of the target from the baseline. This level of deviation could be negotiated, since there is a trade-off between the ambition of the target and the incentives for developing countries. If the target is too ambitious, it will become hard to surpass the target and will create no incentives for certain countries to do better than the target.

Table 4. The share of electricity generation from new capacity in total generation during 2006–2020 at different annual average electricity generation growth rates

Annual average electricity generation growth over 2005–2020 (%/year)	Share of electricity generation from new capacity in total generation from year 2006–2020 (W_{BM})							
	2006	2008	2010	2012	2014	2016	2018	2020
1	0.01	0.03	0.05	0.07	0.09	0.10	0.12	0.14
2	0.02	0.06	0.09	0.13	0.16	0.20	0.23	0.26
3	0.03	0.08	0.14	0.19	0.23	0.28	0.32	0.36
4	0.04	0.11	0.18	0.24	0.30	0.35	0.40	0.44
5	0.05	0.14	0.22	0.29	0.36	0.42	0.47	0.52
6	0.06	0.16	0.25	0.33	0.41	0.47	0.53	0.58
7	0.07	0.18	0.29	0.38	0.46	0.52	0.59	0.64
8	0.07	0.21	0.32	0.42	0.50	0.57	0.63	0.68
9	0.08	0.23	0.35	0.45	0.54	0.61	0.67	0.73
10	0.09	0.25	0.38	0.49	0.58	0.65	0.71	0.76

In this article, the weighting factors for the sectoral target at 10 per cent annual average generation growth is set to differ from those of the sectoral baseline at the same annual average growth by 0.25 (see Table 5), similar to the approach used in the CDM. That is, for countries with BM_{2005} lower than AOM_{2005}, W_{BM} of the sectoral target is set equal to W_{BM} of the sectoral baseline plus 0.25. For countries with BM_{2005} higher than AOM_{2005}, W_{BM} of the sectoral target is set equal to W_{BM} of the sectoral baseline subtracted by 0.25.

The standard for new power generation projects is determined by finding the value of the average emissions intensity of all new plants added after 2005 that makes the average emissions intensity in 2020 equal to the value of the sectoral target at the 10 per cent annual average generation growth, if the annual average electricity generation growth in each country is 10 per cent (i.e., W_{BM} = 0.75 and W_{AOM} = 0.25) (see Table 5). This standard for new power generation projects is to be used as the basis for issuing credits and imposing taxes.

The sectoral target at the actual per cent annual average generation growth in each country could be calculated ex-post based on the standard for new power generation projects and the share of electricity generation from new capacity in total generation in 2020 at the actual electricity generation growth (see the value from Table 5, column year 2020).

As an alternative to the approach where the sectoral target is set ex-ante at a specific value based on an assumption on the annual average generation growth or the range of the generation growth presented in (Amatayakul et. al. 2008, Amatayakul et. al, 2009), the sectoral target for each country in this article is not fixed at a specific value, but set to vary, dependent on the annual average generation growth. As a result, this approach allows the power plant emissions standard to be set at a fixed value instead, independent of the electricity generation growth. This implies that, under this approach, it does not matter how fast the electricity generation growth rate would be in a country, but all new power plants in the country would be encouraged to meet the power plant standard. This approach thus reduces the risk of overestimating the sectoral target or setting the sectoral target too conservative.

The sectoral baseline at the actual per cent annual average generation growth in each country could also be calculated ex-post at the value of the combined margin emissions intensity in 2020 at the actual per cent annual average generation growth.

Table 5. The values of the sectoral emissions intensity baseline and target (i.e., the values of the national average emissions intensity in 2020 (CM_{2020})) and the power plant standard (gCO_2/kWh) during 2013-2020

	For countries with $BM_{2005} \le AOM_{2005}$	For countries with $BM_{2005} > AOM_{2005}$
Sectoral Baseline*	$= 0.25 \times AOM_{2005} + 0.75 \times BM_{2005}$	
Sectoral target*	$= BM_{2005}$#	$= 0.5 \times AOM_{2005} + 0.5 \times BM_{2005}$##
Power plant standard	= (Sectoral target*- $0.25 \times AOM_{2005}$) ÷ 0.75	
Sectoral target**	= W_{AOM}**× AOM_{2005} + W_{BM}**× Target for new projects	

* at 10 per cent annual average generation growth
** at the actual per cent annual average generation growth in each country
#: W_{BM} of the sectoral target* = W_{BM} of the sectoral baseline* + 0.25
##: W_{BM} of the sectoral target* = W_{BM} of the sectoral baseline* – 0.25
W_{BM}** = the share of electricity generation from new capacity in total generation in 2020 at the actual electricity generation growth (see the value from Table 4, column year 2020); W_{AOM}** = 1- W_{BM}**

Based on the approach used in this article, how the values of the sectoral baseline and target at the 10 per cent annual average generation growth and the power plant standard are calculated is presented in Table 5. It should be noted that the value of the power plant standard would be lower than the value of the national generation-weighted average baseline emissions factor for CDM power projects shown in Table 2 and the value of the build margin emissions intensity based on 2005 in all the seven countries (see Table 6). For a comparison, the emissions intensity standard implemented in several states in the U.S. (including California, Washington, New Mexico) is set at 500 gCO_2/kWh (Rubin, 2009).

Table 6. Average operating margin and build margin emissions intensity of seven countries based on 2005, sectoral emissions intensity baseline and target at the 10 per cent annual average generation growth, and the power plant standard for new projects during 2013-2020 and its corresponding efficiency of power plants

Emissions intensity (kgCO2/kWh)	China	India	Indonesia	South Korea	Mexico	Thailand	South Africa
AOM_{2005}	860	960	740	460	550	540	950
BM_{2005}#	800	680	940	370	370	450	1004
Sectoral baseline*	820	820	790	390	460	470	1001
Sectoral target*	800	680	840	370	370	450	990
Power plant standard	780	590	870	340	310	420	1001
Efficiency of power plants** corresponding to the power plant standard	Coal 43.7% or Oil 35.5%	Gas 34.2 %	Coal 39.1% or Oil 31.9%	Gas 59.4 %	Coal with carbon capture or RE	Gas 48.1%	Coal 33.9%

#for Indonesia, based on 2006
*at 10%/year annual average electricity generation growth
**For a reference, emissions intensity (gCO_2/kWh) and corresponding efficiency of new available fossil-based power generation technology are: Coal: 757-959 (45-35.5%), Oil: 603-924 (46-30%), Gas: 337-673 (60-30%) based on (UNFCC, 2007; IPCC, 1996), Coal with carbon capture: 65-152 based on (Rubin, 2009)

3.2 Assessment of the potential emissions reduction, reduction credits and emissions to be taxed

Projections are made for (1) electricity generation growth and (2) scenarios of increased average efficiency of fossil power plants and decreased share of all fossil electricity. In this article, the volume of emissions reduction, the number of reduction credits and the volume of emissions to be taxed are assessed based on the power plant standard set in Table 6, and, for a comparison, based on the power plant standard set at the value of the build margin emissions intensity based on 2005.

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 per cent in South Africa and Mexico, 4.5 per cent in India, 6.5 per cent in Thailand and Indonesia, and 8 per cent in South Korea. For comparison, the reference scenario of World Energy Outlook has a 4.9 per cent annual growth in India during 2004–2030 (WEO, 2006). For China, the annual average growth during 2000–2005 is estimated at 12.6 per cent. However, the annual average growth from the base year 2005 is set to 6.5 per cent, based on the Chinese goal of quadrupling the country's 2000 GDP by 2020 (implying an annual average GDP growth rate of 6.5 per cent from 2005–2020) and on the assumption that electricity demand will grow at the same rate as GDP during 2005–2020 (Kahrl and Roland-Holst, 2006; Cai et al, 2007). Based on this assumption, the electricity generation in China would grow to 6,400 TWh in 2020 (see Figure 2), which is somewhat higher than a projection for electricity demand made by China Development Bank (Kahrl and Roland-Holst, 2006).

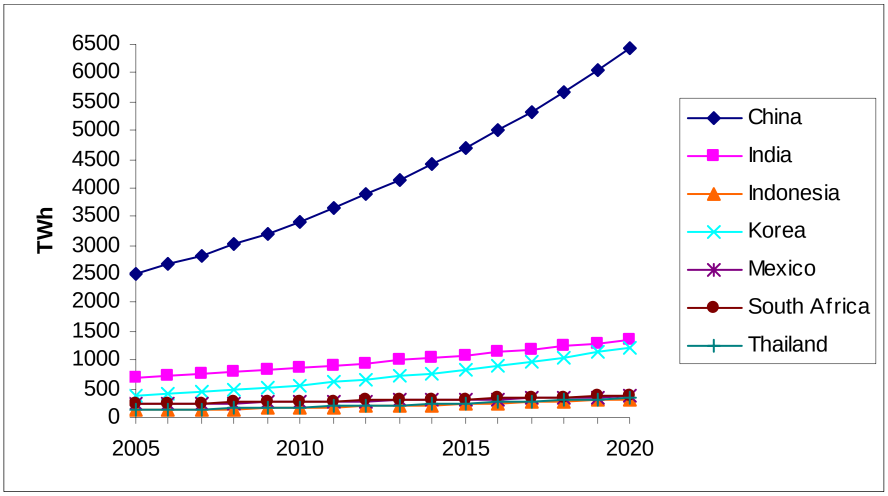

Figure 2. Projected electricity generation in the seven countries from 2005–2020

Scenarios

In order to meet the emissions intensity standard for new power generation projects during 2013-2020, countries have flexibility to choose to implement different options, including (1) building new power plants or expanding capacity of existing power plants based on renewables/CO_2-neutral sources (2) building new power plants or expanding capacity of existing power plants that are low carbon-intensive or high-efficient (3) building new power plants with carbon capture and storage (CCS).

In this analysis, the new capacity added in the different countries during 2013–2020 is focused upon, especially coal and gas-based power plants, which account for a significant share in the generation mix of the build margin of 2005. The following scenarios are defined (see a summary in Table 7);

<u>Ambitious scenario</u>: All coal power plants added during 2013–2020 would have a 40 per cent efficiency and all gas power plants added during the same period would have 50 per cent efficiency (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).

The new capacity added each year during 2013–2020 delivers 12 per cent less coal-based electricity than the build margin in 2005. For China, this scenario implies that the average share of coal-based electricity in 2020 would be about 79 per cent, the same as that of the average operating margin in 2005.

<u>Baseline scenario</u>: All fossil-based power plants added during 2013–2020 in each country would have the efficiency value corresponding to the build margin based on 2005. The share of power generation based on fossil fuels and renewables in each country has the per cent value corresponding to the build margin based on 2005 (see Table 7).

For each scenario, two following cases are investigated. The share of renewables electricity excluding versus including large-scale hydro power.

Table 7. Summary of the ambitious scenario compared with the baseline scenario for the new capacity added during 2013–2020

	Efficiency of all fossil power plants	Share of fossil and renewable electricity added each year
Baseline	Coal (BM*), Gas (BM*), Oil (BM*)	Coal, Gas, Oil, and Renewables (BM*)
Ambitious Scenario	Coal (40%), Gas (50%), Oil (BM*)	Coal (88% of BM*), Gas and Oil (BM*), and Renewables (BM* of renewables +12% of BM* of coal)

BM* = the per cent value corresponding to the build margin based on 2005 (see Table 8); for oil plants, if BM is not available, the per cent value corresponding to the average operating margin in 2005 is used instead.

Table 8. Average operating margin (AOM) emissions intensity in 2005 and build margin (BM) emissions intensity of seven countries based on 2005 and the corresponding generation mix and average efficiency of fossil power plants

Country	Emissions intensity (gCO_2/kWh)		Electricity generation mix (% of total electricity generation MWh)						Fossil power plants average efficiency (%)		
			Coal	Oil	Gas	Hydro	RE[1]	Nuclear	Coal	Oil	Gas
China	AOM	860	79.0	2.4	0.5	15.9	0.1	2.1	32.1	34.6	38.9
	BM	790	90.4	0	1.0	8.2	1.0	0.01	39	-	48.8
India	AOM	970	68.7	4.5	8.9	14.3	1.2	2.5	26.5	32.7	41.9
	BM	680	59.1	1.0	14.2	20.7	0.0	4.9	33.4	NA	44.0
Indonesia	AOM	740	42.9	33.7	14.5	8.9	0	0	34.0	37.9	42.6
	BM	940	88.1	5.8	2.7	0	3.3	0	35.8	NA	NA
South Korea	AOM	440	38.5	6.3	16.1	1.0	0.1	38.0	38.7	50.6	48.8
	BM	370	27.6	0	29.6	0	0.1	42.7	37.8	-	48.2
Mexico	AOM	530	14.5	30.2	37.2	12.2	1.1	4.7	39.8	37.8	40.6
	BM	370	0	0.3	87.3	12.3	0	0	-	NA	48
Thailand	AOM	540	15.1	6.6	71.4	4.4	2.5	0	36.4	37.8	42.7
	BM	450	0.1	3.4	89.7	1.4	5.4	0	37.4	40.0	42.3
South Africa	AOM	940	94.1	0	0	0.9	0.3	4.6	33.9	-	-
	BM	1040	100	0	0	0	0	0	32.8	-	-

[1] RE is an abbreviation for renewable-based electricity excluding hydroelectricity
NA (not available)

The annual volume of emissions reduction in the ambitious scenario compared to the baseline is calculated based on the per cent decrease in the share of coal-based electricity or/and the increases in the efficiencies of coal and gas power plants of the ambitious scenario compared with the baseline scenario.

The annual number of emissions reduction credits generated is calculated based on the share of coal-based electricity and the efficiencies of coal and gas power plants in the ambitious scenario, and on the difference between the emissions intensity of new power plants added in the ambitious scenario and the power plant emissions intensity standard.

The annual number of tax reduction is calculated the same way as the emissions reduction credits but based on the difference between the emissions intensity of new power plants added in the ambitious scenario and that in the baseline scenario (if the emissions intensity of power plants in the ambitious scenario is above the power plant standard), or based on the difference between the emissions intensity of new power plants added in the baseline scenario and the power plant emissions target (if the emissions intensity in the ambitious scenario is below the power plant standard).

The volume of emissions taxed on new power generation projects with an emission intensity above the power plant standard is calculated based on the difference between the emissions intensity of new power plants added in the ambitious scenario and the power plant standard.

3.3 Data sources

National data on fuel consumption and electricity generation used for calculating the average operating margin based on 2005 (AOM_{2005}) for all the seven countries are taken from IEA (IEA, 2007). The emissions factor for coal is 95.8 gCO_2/MJ for India and 94.4 gCO_2/MJ for Indonesia (based on UNFCCC, 2008a and UNFCCC, 2008f, respectively), and is 94.6 gCO_2/MJ for the other countries (based on IPCC, 1996). The emissions factor for lignite is 101.2 gCO_2/MJ for Thailand (based on IPCC, 1996). The emissions factors for other fossil fuels (oil 77 gCO_2/MJ and natural gas 56.1 gCO_2/MJ) are based on IPCC (1996).

The values of the build margin emission factor for all the seven countries shown in Table 8 are taken from the Project Design Documents (PDDs) of CDM projects that supply electricity to the grid (UNFCCC, 2008a-g). The build margin emission factor for India reported in the PDD was taken from the baseline emission factors database for the various electricity grids in India published by the Central Electricity Authority of India. The build margin emission factor for China reported in the PDD was taken from related documents published by the Chinese Office of National Coordination Committee on Climate Change. The 2005 build margin value for China is the generation-weighted average value of the build margins of seven regional grids in China, and is weighted by additional generation in 2005 in each region. Electricity generation mixes and average efficiency of fossil power plants that correspond to the average operating and build margin emissions intensity in each country are based on our own calculation and data from IEA (2007) and UNFCCC (2008a-g).

4. Results

The sectoral baseline for all the seven countries except Indonesia and South Africa would go downward (Figure 3). The assessment shows that the total CO_2 emissions from electricity generation in all the seven countries in the baseline scenario are expected to more than double to 7,800 million tonnes ($MtCO_2$) in 2020 from 3,500 $MtCO_2$ in 2005. In the ambitious scenario, the total average emissions reduction in the seven countries would amount to 480 $MtCO_2$/year. Most of the emissions reduction would occur in China (Figure 4).

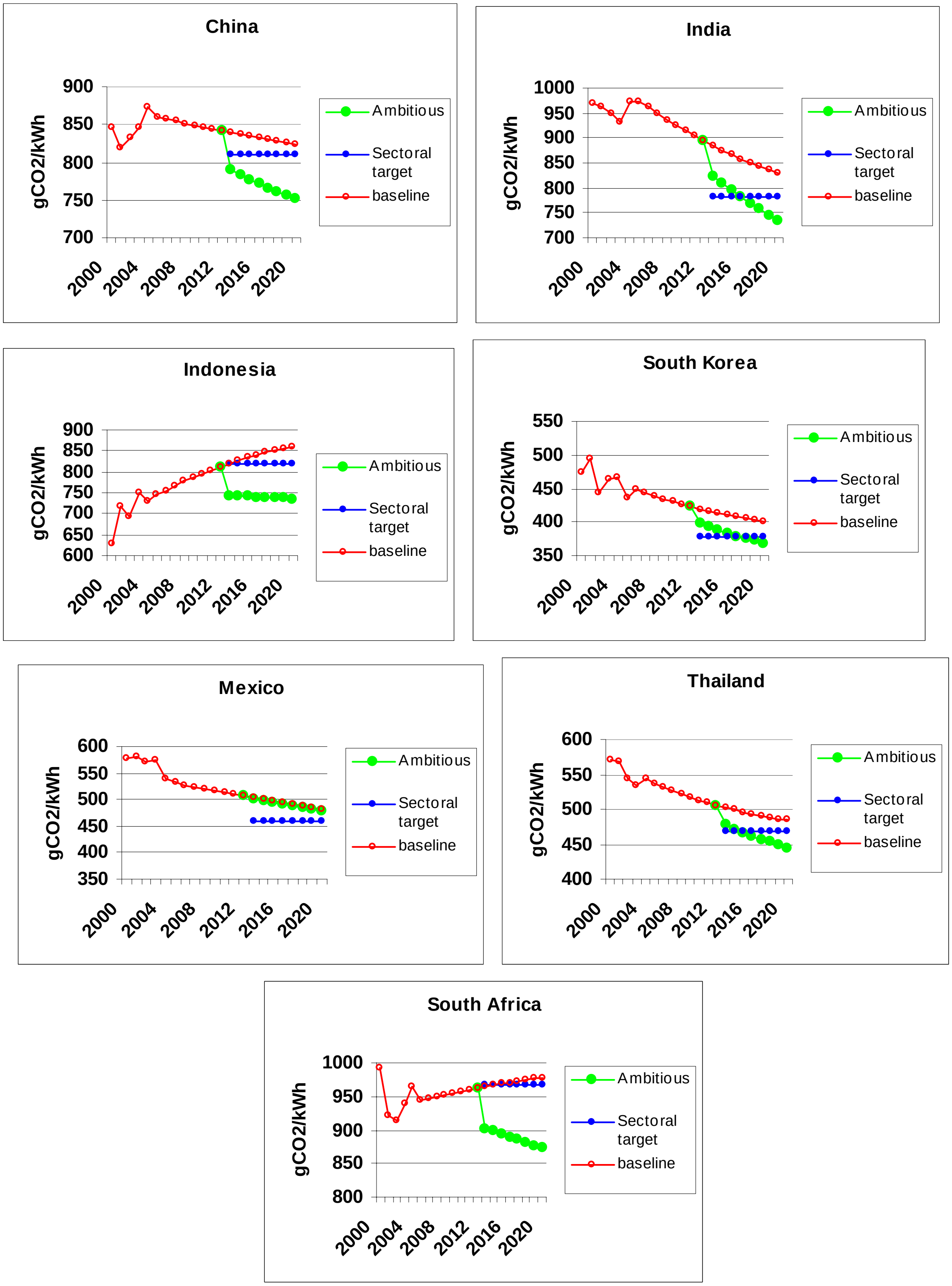

Figure 3. Historical national average carbon intensity in electricity sector from 2000-2005 and projected national average carbon intensity of the baseline, sectoral targets and ambitious scenario from 2006-2020 for seven countries at the assumed annual average electricity generation growth (In this article, the credits are not calculated against the sectoral target in the way proposed in the sectoral no-lose target scheme, but are calculated against the power plant emission standard)

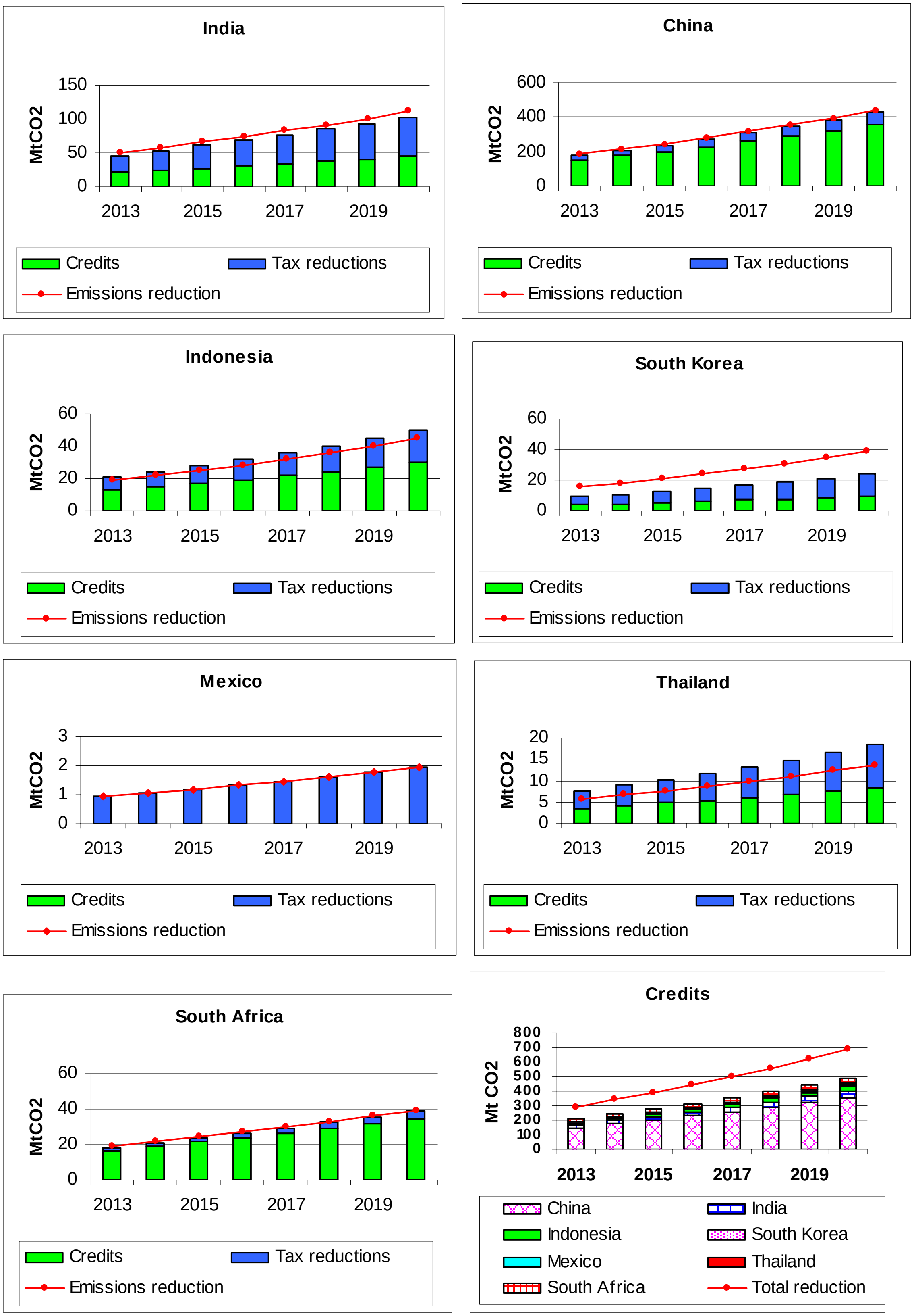

Figure 4. Emissions reduction, reduction credits, and tax reductions during 2013-2020 of the ambitious scenario calculated based on the set power plant standard (in the case where renewalbes power does not include hydro power)

In the case where renewables power does not include hydro power, the annual average number of credits generated in all the seven countries during 2013-2020 based on the set power plant standard would be less than the annual average reduction. The annual average credits in all these countries would amount to 340 $MtCO_2$ (see Table 9). For all countries except Thailand, Indonesia, and South Korea, the annual average reduction is about equal to the sum of credits and tax reductions. The sum of credits and tax reductions generated in Thailand and Indonesia slightly exceeds the annual average reduction because there is a certain share of renewable electricity in the baseline scenario (this implies that a small share of new renewable power generation projects in these countries would have happened without the credits). The sum of annual average credits and tax reductions in South Korea is less than the annual average reduction. This is because the difference between the emissions intensity of coal power plants in the baseline scenario and the intensity of renewable power plants in the ambitious scenario (i.e., the level of reduction) is significantly larger than the difference between the power plant standard and the emissions intensity of renewable power plants (i.e., the level of credits).

The assessment shows that if taxes are not imposed and there are no tax reductions, there may be no incentives for countries, for example, to increase the efficiency of coal and gas power plants from the level that corresponds to an emissions intensity level still far above the power plant standard to the efficiency level in the ambitious scenario.

Table 9. Annual average emissions reduction, reduction credits, and emissions to be taxed ($MtCO_2$) of the ambitious and baseline scenarios calculated based on the power plant standard set in Table 6 (for comparison, the numbers in bracket are calculated based on the power plant standard set at BM_{2005})

	Ambitious				Baseline			
	Reduction	Credit (excl. hydro)	Credit (incl. hydro)	Tax*	Reduction	Credit (excl. hydro)	Credit (incl. hydro)	Tax*
China	304	248 (254)	421 (432)	153 (111)	0	18 (19)	192 (197)	228 (179)
India	79	32 (41)	89 (107)	66 (43)	0	9 (15)	66 (81)	121 (96)
Indonesia	31	21 (29)	21 (29)	-	0	5 (6)	5 (6)	16 (8)
South Korea	26	7 (7)	7 (7)	70 (66)	0	-	-	87 (83)
Mexico	1	0 (0)	4 (4)	-	0	0 (0)	4 (4)	-
Thailand	9	6 (10)	7 (11)	-	0	3 (4)	4 (4)	0.1 (0.1)
South Africa	29	25 (28)	25 (28)	-	0	0 (0)	0 (0)	3 (0.2)
Total	480	339 (370)	573 (619)	289 (220)	0	36 (44)	271 (293)	456 (367)

*emissions to be taxed

If the power plant standard is simply set to the build margin emissions intensity based on 2005, a larger number of credits would be generated for most of the seven countries. In addition, the annual average credits generated would exceed the annual average reduction in Thailand where the share of renewable electricity in the baseline scenario is not negligible and relatively higher than that of the other countries. However, overall, the total annual average credits generated in all the countries would still be less than the total annual average reduction during 2013-2020 (Table 9). In this case, the annual average credits would be 370 $MtCO_2$.

The annual average emissions from coal power plants in the ambitious scenario (i.e., at 40 per cent efficiency) would be taxed in China, India and South Korea. The annual emissions to be taxed would be lower when the power plant standard is set at the build margin emissions intensity based on 2005 compared to the standard set below the build margin emissions intensity. This means that if taxes are imposed, it would incur an additional cost to build new coal plants at 40% efficiency in these countries. From a climate mitigation perspective, this implies that there would be incentives for these countries to build coal power plants with a higher efficiency than 40% or not to build coal power plants. Although the power plant standard set below the build margin emissions intensity incurs a higher cost to build new coal power plants, it ensures that the annual average credits generated would not exceed the annual average reduction in each country and the total credits generated in all the seven countries would not exceed the total reduction (Table 9).

If the countries would continue to follow the baseline scenario instead of trying to achieve the ambitious scenario, the annual emissions to be taxed in each country would be much higher in the baseline scenario than in the ambitious scenario (Table 9). If the value of tax is set at a right level, this implies that there could be strong incentives for these countries to do better than the ambitious scenario. However, the assessment shows that the power plant standard set below the build margin emissions intensity based on 2005 would allow China, India, Thailand and Indonesia to gain some credits (Table 9) because there is a certain share of renewable electricity in these countries and a certain share of gas-based power in China in the baseline scenario.

In the case where renewables power includes hydro power, the annual average number of credits generated in all the seven countries during 2013-2020 based on either the set power plant standard presented in Table 6 or the build margin emissions intensity based on 2005 would exceed the annual average reduction (Table 9). In addition, even if the countries follow the baseline scenario, a lot of credits would still be generated in China, India, Indonesia Mexico, and Thailand because there is a significant share of renewables including hydro power in the baseline scenario in these countries.

5. Concluding remarks and policy implications

In this article, a project-based crediting mechanism which is based on a national emissions intensity standard for new power generation projects to be added from 2013-2020 in developing countries is proposed and investigated. The assessment shows that this mechanism could send a clear signal (through both credits and taxes) directly to all major power generation companies and utilities planning to build new power plants and thus ensure that the overall emissions performance of the power sector would be significantly improved. The mechanism could lead to a participation of both the government and the private sector in reducing the emissions. This mechanism is based on mechanisms that have been proposed or already been implemented, including the sector no-lose target, the sectoral CDM, the environmental performance standard and the carbon tax.

The combined margin approach used in the CDM is used as a basis for setting the power plant emission intensity standard which is set to correspond to a sectoral target set below the business-as-usual intensity level in the electricity generation sector. The level of the deviation of the sectoral target from the business-as-usual intensity level could be negotiated. This approach allows an objective approach for setting the power plant standard in developing countries.

The assessment shows that setting the standard for new projects below the business-as-usual emissions intensity level could help improve and ensure the environmental integrity of the mechanism (i.e., that the annual number of credits generated would not exceed the reduction volume in each country).

Excluding some types of projects that are already common in each country from gaining credits could also help improve and ensure the environmental integrity of the mechanism. Types of projects in developing countries that should not be eligible for credits may be identified and negotiated. Experience on how the government in developing countries has subsidized projects (e.g., cogeneration and renewable power generation projects) using money from its own fund described in, for example, (Amatayakul and Sangarasri Greacen, 2002) may also provide a perspective to address this issue.

Any developing countries could voluntarily participate in this mechanism. If countries would participate in gaining credits from this mechanism, the government of the countries would be required to either regulate/prohibit new plants or impose taxes on new plants with an emission intensity above the power plant standard. If taxes are imposed, the tax revenues gained may be used by the government for supporting other renewable projects such as small-scale renewable projects or for adapting to climate change in the countries. However, for the least developed developing countries, in order to participate in the mechanism, it may not be required to regulate or impose taxes on new plants.

The scope of this mechanism could include only new power generation projects (new plants and capacity expansion plants) with a capacity larger than a specific capacity such as 10 MW. Another mechanism may be designed to cover existing power plants. The standard could also be set for a second phase of the crediting period such as during 2021-2028 but at an even stricter emissions intensity value in order to provide incentives for the government and the private sector to participate in the mechanism early. The value of the tax may be fixed at a specific value and adjusted after a certain period.

The present assessment shows that a significant reduction of CO_2 emissions could be achieved in the power sector by decreasing the share of coal-based electricity and boosting the efficiency of coal power plants in new generation capacity during 2013–

2020 in the seven countries. Given the set power plant emission standard, substantial volume of credits would be generated.

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