Energy Policy 35 (2007) 3675–3680

ENERGY POLICY

www.elsevier.com/locate/enpol

All CO_2 is equal in the atmosphere—A comment on CDM GHG accounting standards for methane recovery and oxidation projects

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Received 22 August 2006; accepted 18 December 2006
Available online 6 March 2007

Abstract

Greenhouse gas (GHG) accounting with respect to two categories of methane recovery and oxidation activities (coal bed or coal mine methane recovery and landfill gas (LFG) recovery) within the Clean Development Mechanism (CDM) is analysed. It is found that baseline methodologies approved by the CDM Executive Board apply systematically inconsistent assumptions concerning the global warming impact of carbon dioxide emissions from the oxidation of methane. One important implication of the results is that applying the baseline methodologies approved for project activities involving LFG recovery will lead to overestimation of the net GHG abatement effect of such CDM project activities.

Keywords: Baseline methodologies; Clean Development Mechanism (CDM); Landfill gas recovery

1. Introduction

The Clean Development Mechanism (CDM) is one of two so-called project-based flexible mechanisms under the Kyoto Protocol.[1] The Kyoto Protocol and the modalities and procedures contained in Decision 3/CMP.1[2] provide part of the legal framework for CDM. The CDM enables Annex I countries to purchase "Certified Emission Reductions" (CERs) that are generated through project activities that reduce emissions or enhance carbon sinks in non-Annex I countries.

Initially, the CDM market was slow to develop, but market activity increased significantly in 2005 following the introduction of the European Linking Directive, which allowed the use of CERs as compliance units in the EU Emissions Trading System, and the entry into force of the Kyoto Protocol. The volume of project-based emission reductions traded (i.e., contracts for future emission reductions from CDM and JI project activities) was approximately 5 Mt carbon dioxide equivalent[3] (CO_2e) in 2001 and had risen to 106 $MtCO_2$e by 2004 (World Bank/IETA, 2006). In 2004, CDM accounted for 97 $MtCO_2$e traded. From 2004 to 2005 traded volumes of CDM emission reductions more than tripled from 97 to 346 $MtCO_2$e. The CDM portfolio is growing rapidly with over 1300 CDM projects in the pipeline in December 2006[4] and expected average annual emission reductions for the 2008–2012 period amounting to over 0.3 $GtCO_2$e. The average annual emission reductions would thereby approach 2.6% of the 1990 emissions of Kyoto Protocol Parties included in Annex B.

If assessed in terms of the number of credits generated, CDM project activities currently under development are

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[1]Three so-called "flexibility mechanisms" defined in the Kyoto Protocol enable Parties to access cost-effective opportunities to reduce emissions or enhance carbon sinks in other countries. It is generally considered that these mechanisms have the capacity to lower the overall costs of achieving the emissions targets of the Protocol. In addition to CDM, the mechanisms are International Emissions Trading (IET) and Joint Implementation (JI).

[2]Decision 3/CMP.1, "Modalities and procedures for a CDM as defined in Article 12 of the Kyoto Protocol."

[3]See Section 3 of this paper for a definition of carbon dioxide (CO_2) equivalent.

[4]⟨http://cdm.unfccc.int/Statistics⟩.

0301-4215/$ - see front matter
doi:10.1016/j.enpol.2006.12.021

concentrated in two sectors: electricity generation (predominantly renewable electricity projects), 24%, and non-CO_2 gases, 54%. Among project activities addressing non-CO_2 gases, decomposition of N_2O from industrial processes represents 21% of CERs generated followed by landfill gas (LFG) recovery, 13%, decomposition of so-called F-gases, 10%, and other methane (CH_4) reductions, 10% (Ellis et al., 2007).

The "baseline" of a CDM project activity is "the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases (GHG) that would occur in the absence of the proposed project activity". Furthermore, a baseline "shall cover emissions from all gases, sectors and source categories listed in Annex A (of the Kyoto Protocol, authors' comment) within the project boundary". A project's eventual emission reductions are determined by taking the difference between the baseline and the actual GHG emissions of the project. In essence, this difference should be a representation of the project's "real" GHG emission impact. A "baseline methodology" is the approach taken to identify the baseline scenario and quantify the emissions in this scenario and in a scenario with the proposed project, and estimate a project's emissions reductions.

Approval of baseline methodologies is the responsibility of the CDM Executive Board (CDM-EB) acting under the authority and guidance of the meeting of the Parties to the Kyoto Protocol (COP/MOP). Once methodologies are approved, they serve as precedents for coming projects, which make them powerful as they may govern not one but several projects.

2. Aim

The recovery and oxidation of CH_4 from landfills and coal beds/coal mines are two categories of activities in the CDM that share common characteristics. However, there is a fundamental difference between the treatment of CO_2 emissions from CH_4 oxidation in baseline methodologies that apply to the recovery and oxidation of LFG and coal bed/coal mine methane, respectively. The aim of this paper is to analyse approved CDM baseline methodologies for the two categories of project activities in question, focusing on the treatment of CO_2 emissions from CH_4 oxidation and the implications thereof. Furthermore, the paper seeks to identify and discuss possible explanations behind the differences with respect to how CO_2 emissions from CH_4 oxidation are treated in the approved baseline methodologies.

It is important to clearly distinguish between the project-based level and the general level. We therefore emphasise that this analysis applies to GHG accounting under the CDM, but not to GHG accounting on the general level.

3. GHG balances of activities involving the collection and oxidation of CH_4 from landfills and coal beds/coal mines

CH_4 and CO_2 are among the GHGs regulated by the Kyoto Protocol. While CH_4 has a shorter lifetime in the atmosphere than CO_2 it is a much more powerful absorbent of heat radiation. The global warming potential (GWP), a measure of the contribution to global warming over a certain time period by a given mass of a GHG, uses a relative scale, which compares the gas in question to CO_2 (whose GWP is one) (Intergovernmental Panel on Climate Change, 2001). The GWP100 of CH_4 is 21, which thus represents that CH_4 is a 21 times more powerful GHG than CO_2 per mass unit over a 100 year period. GHG emissions are commonly reported in terms of CO_2e which is determined by multiplying the amount (in mass units) of emissions of a particular gas by the GWP of the gas.

Globally, landfills and coal production are two significant sources of CH_4 emissions. The mechanisms behind the GHG emissions from these two sources can be summarised as follows:

- *Landfills*: CH_4 is formed in, and subsequently released from, landfills where organic matter decays in an anaerobic environment. LFG emissions consist mainly of CH_4 and CO_2, with a CH_4 fraction that usually varies between 0.4 and 0.6 (Intergovernmental Panel on Climate Change, 2000, p. 5.10).
- *Coal mines*: Coal and CH_4 and are formed together during coalification, a process in which plant biomass is converted by biological and geological forces into coal. The release of CH_4 stored in coal seams and the surrounding strata occurs during coal mining.

If CH_4, that would otherwise have been released to the atmosphere, is recovered and oxidised, CO_2 is emitted instead of CH_4. Considering the stoichiometry of the reaction, the GWP100s and the molar masses of CH_4 and CO_2, respectively, oxidisation of this CH_4 reduces the climate impact by approximately 87%.

More specifically, the following effects of LFG and coal bed/coal mine CH_4 recovery projects have an impact on GHG emissions:

(i) The recovered CH_4 is oxidised and thus not emitted,
(ii) CO_2 formed through CH_4 oxidisation is emitted, and
(iii) Heat recovered from CH_4 oxidation may be used to generate useful heat and/or electricity, which in turn might displace heat and/or electricity from another source, whereby an indirect result could be some degree of avoided fossil fuel combustion.

Note that the direct emission of CO_2 to the atmosphere, which occurs due to an LFG or a coal bed/coal mine CH_4 recovery and oxidation project, would not have occurred spontaneously in the absence of the project.

4. Review of approved CDM baseline methodologies

4.1. GHG accounting in baseline methodologies for LFG recovery projects and coal bed/coal mine CH_4 recovery projects

We reviewed all of the CDM baseline methodologies that have been approved to date for the two project categories LFG recovery and coal bed/coal mine CH_4 recovery.[5]

Based on the information contained in the reviewed baseline methodologies, it can be established that the two project categories feature very similar characteristics:

- For coal bed/coal mine CH_4 recovery project activities, the CH_4 is released to the atmosphere in the absence of a recovery project, i.e., in the project's baseline.
- For LFG project activities, biodegradable matter is landfilled in the baseline and a fraction of the matter will decompose anaerobically, thus leading to LFG being emitted (The ACM0001 consolidated baseline methodology for LFG recovery projects clearly states "the baseline is the atmospheric release of the gas").

It follows that, for both project categories, the CO_2 emissions that do occur instantly due to oxidation of CH_4 in the project activity would not have occurred in the baseline. For both project categories the CO_2 emitted should, therefore, be subtracted from the GHG reductions achieved in order to obtain a representation of a project's "real" emission reduction. However, our review has identified an error with respect to GHG accounting in methodologies for LFG recovery projects. These methodologies exclude the CO_2 emissions due to CH_4 oxidation from the accounting, i.e., they are regarded as zero. In fact, ACM0001 explicitly states that:

> Possible CO_2 emissions resulting from combustion of other fuels than the methane recovered should be accounted as project emissions.

[5]The methodologies concerned are: ACM0001 "Consolidated baseline methodology for landfill gas project activities"; AM0002 "GHG emission reductions through LFG capture and flaring where the baseline is established by a public concession contract"; NM0005-rev "Nova Gerar LFG to Energy Project"; NM0010-rev "Durban-LFG-to-electricity project"; NM0021 "Cerupt methodology for landfill gas recovery"; NM0032 "Municipal Solid Waste Treatment cum Energy Generation Lucknow, India"; ACM0008 "Consolidated methodology for coal bed methane and coal mine methane capture and use for power (electrical or motive) and heat and/or destruction by flaring"; NM0066 "Coalmine methane utilization project at Nanshan Mine, China"; NM0075 "Pansan coal mine methane utilisation and destruction"; NM0093 "Fuxin coal mine methane (CMM)/coal bed methane (CBM) utilisation project"; NM0094 "Huainan Panyi and Xieqiao coal mine methane utilisation project"; and NM0102 "China Jincheng coal mine methane power generation project". All reviewed methodologies are available on the UNFCCC web site, see 〈http://cdm.unfccc.int/methodologies/PA-methodologies/approved.html〉.

Thus, in estimating the GHG emission reduction, the avoided CH_4 emissions, any CO_2 emissions from the project except CO_2 emissions from LFG oxidation, and any impact due to indirectly avoided fossil fuel combustion[6] are taken into account.

In contrast, according to methodologies for coal bed/coal mine CH_4 recovery projects, the CO_2 emissions due to CH_4 oxidation are included in the accounting. The consolidated baseline methodology for coal bed/coal mine CH_4 recovery projects (ACM0008) states that:

> For the purpose of determining project activity emissions, project participants shall include:
> CO_2 emissions from the combustion of methane in a flare, engine, power plant or heat generation plant …

Thus, the result of our review shows that the methodologies apply systematically inconsistent assumptions concerning the global warming impact of CO_2 emissions from the oxidation of CH_4. One consequence that follows from this inconsistency is that the net GHG abatement in baseline methodologies for LFG recovery activities is overestimated.

4.2. The evolution of GHG accounting in LFG baseline methodologies

We have established that there are systematic inconsistencies with respect to the accounting of CO_2 emissions from CH_4 oxidation between CDM baseline methodologies designed for LFG recovery and coal bed/coal mine CH_4 recovery project activities. In this section, we aim to identify and discuss possible explanations as to why the CO_2 emissions from CH_4 oxidation in LFG recovery project activities are omitted from the GHG accounting. The discussion is mainly based on early drafts of proposed new methodologies for LFG projects and documents containing information from the review and approval process (under the CDM-EB) to which the methodologies have been subjected.[7]

We identified that in early drafts of the new proposed methodologies NM0010 ("Durban LFG to electricity project") and NM0021 ("Cerupt methodology for LFG recovery") it is noted that CO_2 emissions from LFG recovery projects are not accounted under the 1996 Revised IPCC Guidelines, since the CH_4 originates from anaerobic decomposition of biomass (Intergovernmental Panel on Climate Change (IPCC), 1997). Against this background, it is argued in the proposed methodologies that CO_2 emissions from the oxidation of CH_4 should not be included in the total project emissions.[8]

[6]For an explanation regarding indirect effects, refer to item (iii) in Section 3 concerning GHG balances.

[7]All review reports and public inputs as well as draft proposed methodologies are available at http://cdm.unfccc.int/methodologies/PA-methodologies/approved.html.

[8]Reporting guidelines for national GHG inventories are being developed within the United Nations Framework Convention for Climate

The issue of the LFG originating from decomposed biomass is discussed further in a public input (L. Schneider) on proposed new methodology NM0021. In the public input the author argues that the assumption based on the guidance provided by the Revised IPCC Guidelines is partly incorrect:

> According to the 1996 Revised IPCC Guidelines, CO_2 emissions from biomass, which is regrown on an annual basis, are in fact not accounted. However, 'if biomass raw materials are not being sustainably produced, the net CO_2 release should be calculated and reported under the Agriculture and Land-Use Change and Forestry Chapters' […] In this regard, if the waste contains biomass that has not been produced in a sustainable manner […], the relevant fraction of CO_2 emissions resulting from combustion of methane should be accounted. In this case, the project activity does not change the quantity of unsustainably produced biomass, but increases the CO_2 emissions resulting from this source …

As a background note, let us first point out that IPCC guidelines for inventories and accounting are specifically aimed at reporting and accounting of national GHG balances, while CDM projects are project-based activities where accounting is carried out in relation to a project-specific baseline. Then let us demonstrate the irrelevance of the arguments presented in draft baseline methodologies NM0010 and NM0021 and the public input referred to earlier in this section by considering the two following examples:

Example 1. All landfilled biomass in the baseline comes from sustainable biomass production:

> In the baseline of this example, there is no long-term change with respect to the carbon stock in standing biomass. The biomass in question is landfilled and LFG is released to the atmosphere. The project does not change the biomass production or the landfilling activity, but involves oxidisation of a certain share of the CH_4 otherwise released whereby instant emissions of CO_2, that would not occur in the baseline, displace CH_4 emissions.

Example 2. All landfilled biomass in the baseline comes from unsustainable biomass production:

> In the baseline of this example, there is a long-term reduction with respect to the carbon stock in standing biomass. The biomass in question is landfilled and LFG is released to the atmosphere. The project does not change the biomass production, carbon stock deterioration, or the landfilling activity, but involves oxidisation of a certain share of the CH_4 otherwise released whereby instant emissions of CO_2, that would not occur in the baseline, displace CH_4 emissions.

Consequently, it does not matter whether the source of the landfilled biomass is one where regrowth occurs or not. It then follows that, although the CH_4 originates from decomposition of biomass, excluding the CO_2 emissions from CH_4 oxidation will lead to exaggerated estimations of the projects' emission reductions.

Interestingly, in one evaluation report from the review of the proposed new methodology NM0010, the expert reviewer (J. Anderson) notes that it is the difference between the climate impact of CH_4 emissions and CO_2 emissions from the degraded waste that should be accounted for in order to get a correct estimate of the GHG mitigating impact of CH_4 oxidation:

> The project counts its reductions as the amount of methane avoided from release; this methane is converted to CO_2 by combustion. This CO_2 is not included as an emission because it is the same CO_2 as had been sequestered in the organic matter that later produced the CH_4 and therefore the process is carbon neutral. Whether the CO_2 is counted as an emission depends on where the lines are drawn around the carbon cycle: from the perspective of the project boundary, waste turns to CH_4 or waste turns to CO_2—in the first case emissions have a GWP of […] 21 […], in the second there is a GWP of 1; the difference is what is logical to count.

In spite of this note having been drawn to the CDM-EB's Methodology Panel's attention, the panel, in its recommendation concerning NM0010 to the CDM-EB, states: "The CO_2 and other minor gases like CH_4 and N_2O from methane combustion are ignored. It can be accepted that CO_2 from methane is biogenic and is accounted for in growth of biodegradable waste." In relation to this statement one may note that neither growth nor decline in biodegradable waste is accounted for under the Kyoto Protocol, see Section 5.

5. Considering double counting

It has now been demonstrated that CO_2 emitted from oxidation of the CH_4 component of LFG should be subtracted from the GHG reductions achieved in order to

(*footnote continued*)
Change (UNFCCC) with the help of the IPCC. In this process the rules are defined that regulate the national reporting of GHG emissions under the UNFCCC and provide guidance for the national GHG accounting under the Kyoto Protocol. Indeed, CO_2 emission reporting under the UNFCCC and emissions accounting under the Kyoto Protocol are carried out in different ways depending on whether the origin of the material is fossil or biological. National reporting of fossil CO_2 emissions is based on atmospheric flows, which means that the CO_2 flux from specified carbons pool to the atmosphere is estimated in the country where decomposition takes place. On the other hand, the reporting framework in the Land-Use, Land-Use Change and Forestry (LULUCF) sector is based on estimating net carbon stock changes in biomass carbon pools of the reporting country. Only five broadly defined carbon pools are considered (Intergovernmental Panel on Climate Change (IPCC), 2003). Any net decrease in carbon stocks in the included pools is reported as the equivalent CO_2 emission and any net increase is reported as the equivalent CO_2 removal. Combustion of biomass has only an indirect impact on the reported emissions, through biomass harvesting which influences the balance of the five carbon pools.

obtain a representation of a CDM project's "real" emission reduction. It has also been made clear that the origin of the biomass in landfills is of no importance for the atmospheric impact of CDM project activities based on LFG recovery and CH_4 oxidation. The difference between the baseline scenario and the project scenario is the same, regardless of whether the biomass is sustainably produced or not.

Are there, however, any other arguments for not subtracting the CO_2 formed by CH_4 oxidation from the estimated GHG emission reduction for the project? The answer is yes, as there is a risk for double counting if the biomass in question has already been accounted for as oxidised under the Kyoto Protocol. Before we elaborate further on this issue, a brief description of the United Nations Framework Convention on Climate Change (UNFCCC) reporting versus the Kyoto accounting is necessary.

UNFCCC reporting is performed by virtually all countries in the world, while it is only the binding GHG emission targets listed in Annex B of the Kyoto Protocol that provide true incentives to reduce GHG emissions for the limited number of (Annex I) countries committed hereto. Article 3.3 of the Kyoto Protocol lists three compulsory land use, land-use change and forestry (LULUCF) activities, namely afforestation, reforestation, and deforestation and, furthermore, provides the possibility to account for some additional human-induced activities linked to agricultural soils and land-use change and forestry in Article 3.4. Eligible non-compulsory activities were subsequently decided upon in the Marrakesh Accords, and these were forest management, cropland management, grazing land management, and revegetation. As removals of biomass from the land areas connected to Article 3.3 or 3.4 activities will affect the carbon content (carbon pools) in these land areas, any net removals will be accounted for as GHG emissions.[9] Hence, there is a risk that the CO_2 released from biomass, with its origin in 3.3 or 3.4 activities, is accounted for twice, both at harvesting and when the CO_2 is released to the atmosphere, if the CO_2 formed through oxidation of CH_4 in a LFG recovery CDM project is subtracted from the estimated GHG emission reductions.

Since the host countries of CDM projects are non-Annex I countries, however, the only risk for double counting is for imported biomass with its origin in Article 3.3 or 3.4 activities (i.e., biomass imported from Annex I countries), or for domestic biomass with its origin in a LULUCF CDM project, of which afforestation and reforestation are the only eligible activities. Thus, for CDM projects the risk can be considered to be almost negligible, as afforestation and reforestation activities are not probable sources of biomass by definition. Moreover, since baselines for CDM projects shall be established in a "conservative manner" (Decision 3/CMP.1[10]), it ought to be a feasible approach to assume that no biomass derives from 3.3 or 3.4 activities.

However, for LFG projects performed in Annex I countries (i.e. JI), the risk for double counting may be more pronounced, but as the focus here is on CDM activities we consider that issue as being beyond the scope of this paper.

6. Discussion

The IPCC guidelines for GHG inventories approach the issue of CO_2 emissions from biomass combustion from the perspective that if biomass is harvested at an unsustainable rate, net CO_2 emissions will appear as a loss of biomass stock in the LULUCF sector[11] and as such considered in LULUCF in national GHG inventories and to a limited extent in Kyoto accounting. To avoid double counting, emissions from combustion of biomass are therefore not included in the sectoral or national totals of the GHG reporting framework under the UNFCCC. However, as we have shown in this paper, applying the same principle to LFG recovery project activities within the CDM will lead to exaggerated estimations of GHG reductions achieved. We therefore wish to highlight the importance of truly acknowledging that all CO_2 is equal in the atmosphere i.e., that once released to the atmosphere, CO_2 has the same impact on the earth's radiative balance whether the source is a fossil fuel or biomass. For this reason, it is unfortunate when the IPCC provides vague guidance concerning this matter. An illustrative example can be found in the 2006 IPCC Guidelines for national GHG inventories (Intergovernmental Panel on Climate Change (IPCC), 2006) which contains the following statement relating to recovered LFG:

> The emissions from combustion of the recovered gas are however not significant, as the CO_2 emissions are of biogenic origin.

We note that the IPCC's use of "not significant" is likely to leave the reader with a rather vague idea with respect to the reason why CO_2 emissions from combustion of the CH_4 fraction of LFG should not be considered. More precise guidance from the IPCC would be desirable in order to prevent further confusion relating to the impact of CO_2 emissions from biomass.

There is one final implication to which we would like to draw attention. The tradable CERs of CDM projects are generated from projects that are located in countries that have no quantified emission limitation and reduction commitments, while they can be used by Annex I Parties towards meeting their quantified commitments. If the

[9] For Article 3.4 activities this provides that an active choice has been made to include Article 3.4 activities in a nation's GHG accounting.

[10] Decision 3/CMP.1, "Modalities and procedures for a CDM as defined in Article 12 of the Kyoto Protocol."

[11] The 2006 IPCC guidelines for national GHG inventories (Intergovernmental Panel on Climate Change (IPCC), 2006) denotes this sector Agriculture, Forestry and Land-Use (AFOLU).

emission reductions achieved though CDM projects are exaggerated this would lead to underachievement in the Kyoto system. We have shown that the currently applied methodologies for LFG projects include a component that leads to a systematic overestimation of the emission reductions by approximately 13%. In relation to this we note that LFG capture alone accounts for approximately 13% of the estimated emission reductions from proposed CDM projects (see the introduction to this paper). One may conclude that the single error that has been identified in this paper leads to a small but not insignificant overestimation of overall emission reductions generated through CDM projects.

Finally, let us also note that there is a possibility that methodologies designed for other project categories within the CDM feature the same logical error as the one in methodologies for LFG recovery projects that has been identified in this paper.

7. Conclusions

The recovery and oxidation of LFG is a significant category of activities in the CDM. In this paper, we have identified a systematic overestimation of the potential GHG reduction in all of the current approved methodologies developed for LFG recovery projects. For ease of understanding and to highlight the systematic error that leads to the overestimation identified, LFG methodologies were compared to methodologies for coal bed or coal mine methane recovery projects. Furthermore, possible reasons behind the systematic overestimation are discussed. Since the overestimation will elevate the allowed domestic emissions for countries that have undertaken GHG emission reduction commitments and any overestimated GHG reductions will not be met by true GHG reductions elsewhere, the CDM GHG accounting standards ought to be corrected. Such correction would be in line with the criterion that CDM baselines shall be conservative.

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