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Carbon credit for hydroelectric dams as a source of greenhouse-gas emissions: The example of Brazil's Teles Pires Dam

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Abstract Carbon credit is granted to hydroelectric dams under the Kyoto Protocol's Clean Development Mechanism (CDM) under the assumptions that (1) the dams would not be built without CDM funding and (2) over the 7 to 10-year duration of the projects the dams would have minimal emissions as compared to the fossil fuel-generated electricity they displace. Both of these assumptions are false, especially in the case of tropical dams such as those planned in Amazonia. Brazil's Teles Pires Dam, now under construction, provides a concrete example indicating the need for reform of CDM regulations by eliminating credit for hydroelectric dams.

Keywords Amazonia, Dams, Global warming, Greenhouse gas emissions, Hydroelectric dams, Methane, Mitigation

1 Introduction

Carbon credit granted for hydroelectric dams under the current regulations of the Kyoto Protocol's Clean Development Mechanism (CDM) represents a major source of "hot air," or certified emissions reductions (CERs) that allow the countries purchasing them to emit greenhouse gases, but without any real benefit for climate from the mitigation project. As of 30 January 2012 the CDM executive board had approved 406 hydroelectric projects for credit worldwide totaling 70.2 million tons of carbon-dioxide equivalent (CO_2-e), or 19.2 million tons of carbon) (Chu 2012). The projects are either for 7 years (with the possibility of renewal) or for a fixed period of 10 years (as in the case of the proposal for Brazil's Teles Pires Dam). The "pipeline," or projects either registered or seeking registration with the CDM, is much larger (Table 1). The 288 million tons total average CO_2-e per year of credit (78.9 million tons of carbon) in the global pipeline is roughly equal to Brazil's current emissions from Amazon deforestation. Brazil accounts for 6.2% of the pipeline total, and of this the Teles Pires Dam represents 14.0%.

<Table 1 here>

The dams have multiple environmental and social impacts (WCD 2000). There is also strong evidence that virtually none of the supposed emissions reductions is additional (i.e., they would be built anyway, without CDM funding). Virtually all dam projects only apply for CDM credit after the investments in project construction have already been secured, when the dam is under construction (as in the case of the Teles Pires Dam), and sometimes even after the dam has been built. Brazil's current ten-year energy expansion plan calls for building 48 new large dams in the country by 2020, 30 of which would be in the Legal Amazon region (Brazil, MME 2011). Note that since 2006 Brazil defines "large" dams as > 30 MW (most are much larger), while the CDM defines "large" dams as > 15 MW and the International Commission on Large Dams (ICOLD) defines them as > 15 m in height. Building 30 dams in 10 years in Brazilian Amazonia corresponds to one dam every four months, thus providing ample opportunity to claim additional mitigation credit if the current regulations of the CDM continue unchanged. Brazil's National Plan for Climate Change implies that this is, indeed, the expectation of the Brazilian government (Brazil, CIMC 2008), although this in no way implies that these dams would not be built without CDM credit.

The first large dam to request CDM credit in Brazil's Amazon region was the Dardonellos Dam in the state of Mato Grosso, and this has now been followed by the 1820-MW Teles Pires Dam, scheduled for construction on the Teles Pires River, a tributary of the Tapajós River, itself a tributary of the Amazon. The 135-km^2 reservoir will straddle the border between the states of Pará and Mato Grosso. Bidding was held on 17 December 2010 to choose the consortium of firms that will build the dam and sell the electricity (since 2006 Brazil's dams are offered through bidding on the price to be charged for the electricity, the dam being awarded to the company offering the lowest price); contracts were signed on 7 June 2011 and construction officially began on 30 October 2011 (Brazil, PR 2011, p 82). The goal of the present paper is to examine the proposal for crediting Brazil's Teles Pires Dam as an example of the widespread problems affecting dams in the CDM.

2 The Teles Pires project

The Project Design Document (PDD) for the Teles Pires Dam (Ecopart 2011) is revealing both of the flaws in the current CDM system and of the inconsistencies between Brazilian government's stated concern for climate change and its engaging in maximum exploitation of loopholes in CDM regulations. The document begins by stating (p 3) that "*The Project will make use of the hydrological resources of the Teles Pires River …. in order to generate greenhouse gases (GHG) emission free electricity*". No literature is cited here or anywhere in the document to substantiate the claim that Amazonian hydroelectric dams such this one are emissions free. Instead, the calculations later in the document rely on a CDM procedural clause related to the power density of the dam as the justification for using a value of zero for the project's emissions in the calculations. Unfortunately, the fact that Amazonian dams produce large amounts of greenhouse gases, especially during their first ten years of operation (the time horizon for the current CDM project), has been shown in many studies in the peer-reviewed literature (e.g., Galy-Lacaux et al. 1997, 1999; Fearnside 2002, 2004, 2005a, b, 2006a, 2008, 2009a; Delmas et al. 2004; Abril et al. 2005; Guérin et al. 2006, 2008; Kemenes et al. 2008, 2011; Gunkel 2009; Pueyo and Fearnside 2011). While caveats and assumptions are detailed in all of these studies, their overall conclusion that tropical dams emit substantial amounts of greenhouse gases in their first ten years is clear and robust.

Despite the document's using zero as the emission for the project in its calculation of climate benefits, a table is included (p 10, Table 3) indicating that the dam would produce methane (CH_4), although no quantities are mentioned. The same table also states that emissions of CO_2 and N_2O are zero, each of these being only a "*minor emission source*." Unfortunately, both of these gases are also produced. Creating the reservoir will kill forest trees in the flooded area, and these generally remain projecting out of the water; the wood decays in the presence of oxygen and produces CO_2. The quantities are quite substantial over the ten-year time horizon of the current CDM project, as shown by calculated emissions from this source in existing Amazonian reservoirs (Fearnside 1995). CO_2 will also be emitted by deforestation activity stimulated near the dam and by clearing of cerrado (savanna) further upstream in order to produce the soybeans that would be transported on the Teles-Pires/Tapajós waterway, of which this dam and its locks form a part (Fearnside

2001, 2002b; Millikan 2012). Nitrous oxide (N_2O) is also emitted by tropical reservoirs, as has been shown in French Guiana (Guérin et al. 2008).

The proposal takes advantage of a CDM regulation that allows zero emissions to be claimed if the power density is over 10 W/m² (p 27):

"*Emissions from water reservoir are set to zero if the power density of the project activity is greater than 10 W/m^2. The Project power density is 19.18 W/m², thus by definition emissions from water reservoir are zero*".

Unfortunately, having a high power density does not, in fact, result in zero emissions. A high power density means that the area of the reservoir is small relative to the installed capacity. The small area means that emissions through the reservoir surface (from bubbling and diffusion) will be smaller than in a large reservoir, but not zero. The installed capacity, however, reflects the amount of water available in the river, and this has the opposite effect: the more the streamflow the more the emission that will result from water passing through the turbines and spillways. The turbines and spillways are, in fact, the major source of methane emission in most Amazonian dams (e.g., Fearnside 2002a, 2005a,b, 2009, Abril 2005). The water passing through the turbines and spillways is normally drawn from a depth below the thermocline that separates the layers of water in the reservoir. The deeper layer (the hypolimnion) is virtually devoid of oxygen, and decomposition of organic matter therefore generates methane instead of carbon dioxide. Each ton of methane has the impact on global warming of 25 tons of CO_2 over a 100-year time span according to the last report of the Intergovernmental Panel on Climate Change (Forster et al. 2007), and 34 times this impact according to a more recent estimate (Shindell et al. 2009). The water with high concentrations of methane (under pressure at the bottom of the reservoir) is released to the open atmosphere below the dam, and the most of methane quickly emerges as bubbles (Henry's Law). Note that the only valid means of measuring these emissions is by the difference in concentration of methane in the water above the dam (at the depth of the turbines) and in the river below – not by floating chambers to measure flux through the surface of the river some distance downstream, as has been done in several studies that claim only small emissions from "degassing" at the turbines (e.g., dos Santos et al. 2008; Ometto et al. 2011). See comparative data in Kemenes et al. (2011).

The Project Design Document calculates reservoir area for the purpose of computing the power density, which is the installed capacity in Watts divided by the area in square meters. The calculation (p 36) is described as:

"*The project's reservoir area under the normal maximum water level of 220 m is 135.4654 km^2, of which 40.6 km² is part of the normal river bed and, therefore, the increased flooded area is 94.8654 km².*"

The assumption is that the water located over the "normal river bed" is not emitting methane. Unfortunately, this water also emits methane, as shown by numerous studies that have measured reservoir surface fluxes at a variety of monitoring points in Amazonian reservoirs (e.g., Rosa et al. 1997; Duchemin 2000; Abril et al. 2005; Kemenes et al. 2007). The CDM regulation allowing the river bed not to be counted appears to be based on an assumption that the natural river would be emitting the same amount of methane. However, methane emissions from a free-flowing river are much lower than those from reservoirs. Rivers do not normally stratify, especially in the fast-flowing stretches that are appropriate for building hydroelectric dams.

The Project Design Document calculates a benefit of 24,973,637 t CO_2eq over 10 yrs. (p 34, Table 13), based on the loophole of a zero value being permitted for reservoir emissions if power density exceeds 10 W/m^2. The proponents state "*Therefore, once the project's power density is above 10W/m^2, no calculation of project emissions is required*." (p 34). While such a calculation may be "*not required*," the proponents could have opted to make such a calculation based on the best available evidence had they wanted to do so.

The claim of displacing almost 25 million tons of CO_2-equivalent over ten years represents 6.8 million tons of carbon. This "hot air" will contribute to further climate change by allowing the countries that purchase the carbon credit to emit more gases. The money paid for these credits also weakens global efforts to contain climate change by draining funds from the always-inadequate resources available for mitigation. Brazil, as one of the countries expected to suffer most from projected climate changes, stands to lose from such an arrangement. The amounts of carbon involved re significant. As an indication of scale, Brazil's well-known program for replacing gasoline with ethanol in the country's passenger cars in the 1990s is calculated to have displaced 9.45 million tons of carbon per year (Reid and Goldemberg 1998).

The Project Design Document asserts (p 41), without citing any supporting studies, that: "*environmental rules and licensing process policies are very strict in line with the best international practices*." The implication is that dam projects in Brazil will have minimal environmental and social impacts that might embarrass the countries that purchase the resulting CDM credits. However, there is a substantial literature examining the deficiencies in Brazil's licensing system (e.g., Fearnside and Barbosa 1996; Fearnside 2006b, 2007, 2011; Fearnside and Graça 2006; Santos and Hernandez 2009). In the case of the Teles Pires Dam in particular, affected indigenous peoples have strongly protested the impacts and faults in the licensing process (Kayabi, Apiaká and Munduruku 2011). The dam has a long list of impacts and problems in its licensing (Millikan 2011; Monteiro 2011a, b). On 27 March 2012, Brazil's Public Ministry (part of the Ministry of Justice) obtained an injunction halting the dam's construction pending consultation with affected indigenous peoples (MPF 2012). While such injunctions are usually short lived due to the existence of apellate judges who are willing to overturn them, the halting of construction is an indication of both the seriousness of the dam's impacts and of inadequacies in the licensing.

The Project Design Document mentions a "*growing concern*" in Brazil for environmental sustainability (p 41). This should include avoiding the creation of "hot air." This project generates carbon credit without a real climate benefit in two ways. First, it is based on the fiction that the hydroelectric dam will have zero emissions, despite extensive evidence indicating that Amazonian dams have large emissions, especially in the first decade that is the time horizon of the project. Second, the project is not "additional," as required by Article 12 of the Kyoto Protocol in creating the Clean Development Mechanism. Projects are supposed to gain credit only if the claimed emissions reductions would not have taken place without the CDM funding. In this case, the dam is already financed and under construction by Brazilian companies with the full expectation of making a profit from electricity sales without any additional help from the CDM. None of the 25 million tons of CO_2-equivalent claimed is additional.

3 Hydroelectric emissions and the IPCC

The inclusion of hydroelectric dams in Intergovernmental Panel on Climate Change (IPCC) guidelines for national inventories under the United Nations Framework Convention on Climate Change (UN-FCCC) has evolved over time, but methane is still left out of the required reporting. The 1996 revised guidelines included release of carbon stocks in forests that are converted to “flooded lands” (including reservoirs) based on the difference in stock between the two ecosystems, but presuming that all of the release is in the form of CO_2 rather than CH_4 (IPCC 1997). The 2003 IPCC good practice guidelines included an appendix to its wetlands chapter as a “basis for future methodological development” (IPCC 2003, Appendix 3a3). This suggests a Tier 1 (required) accounting for reservoir surface emissions from diffusion and bubbling, and a Tier 2 (voluntary) accounting that would include spillways and turbines. A revision of the guidelines for national inventories in 2006 maintains the limitation of required reporting to emissions of CO_2, but also includes an appendix as a “basis for future methodological development” that includes methane from hydroelectric dams in the “flooded land remaining flooded land” category. The author team, which included a representative of ELETROBRÁS, weakened the proposed future methodology as compared to its predecessor in the 2003 Good Practice Guidelines, removing information indicating greater emissions and reducing the required reporting: Tier 1 would only include the relatively modest emissions occurring by means of diffusion from the reservoir surface, although countries could voluntarily report bubble emissions from reservoir surfaces at the Tier 2 level, the major emissions of methane from the turbines only being included at the rarely used Tier 3 level (Duchemin et al. 2006). At the May 2006 IPCC plenary meeting in Mauritius that approved the 2006 guidelines, Brazilian diplomats tried unsuccessfully to have reservoir emissions from removed from the section on “flooded land” (Earth Negotiations Bulletin 2006; IRN 2006, p 19).

Brazilian influence has been critical in creating and broadening the loopholes in the CDM’s regulations on credit for hydroelectric dams. The CDM methodology panel (2006) proposed considering emissions to be zero for projects with power densities over 10 W m^{-2} based on an internal technical paper by Marco Aurélio dos Santos and Luiz Pinguelli Rosa. Rosa, the former head of ELETROBRÁS, has been advocating 10 W m^{-2} as a criterion since before the Kyoto Protocol (Rosa et al. 1996; see Fearnside 1996) and has long claimed that dams have only very small emissions (Rosa et al. 2004, 2006; see Fearnside 2004, 2006c). In February 2006 the CDM executive board adopted the10 W m^{-2} threshold for presumed zero emissions, and, at the urging of the board’s director (José Miguez, head of the sector of the Brazilian Ministry of Science and Technology responsible for the country’s greenhouse-gas inventories for the UN-FCCC), expanded the crediting for dams not meeting the 10 W m^{-2} beyond what had been suggested by the Meth Panel: lowering from 5 to 4 the minimum power density eligible for credit under the rules and lowering from 100 to 90 gCO_2eq/kWh the presumed emission for dams with power density in the 4-10 W m^{-2} range.

In 2011 the IPCC produced a special report on renewable energy that reviews life-cycle assessments for various technologies. For the typical case (i.e., the 50th percentile), hydropower is ranked as having less than half the emissions impact of any other source, including solar, wind and ocean energy (IPCC 2011, p 982). The basis of this classification is unclear from the report: the table presenting the results describes them as "aggregated results of literature review", but the bibliography appears to contain no studies of hydroelectric emissions. The report also states (p 84) that "*When considering net anthropogenic emissions as the difference in the overall carbon cycle between the situations with and without the reservoir, there is currently no consensus on whether reservoirs are net emitters or net sinks*." However, this concept of "anthropogenic emissions" would only apply if emissions were limited to CO_2, ignoring the role of reservoirs in converting carbon to methane. Full accounting of emissions, including methane, is necessary in order to have valid comparisons of the impact of different energy sources.

4 Conclusions

Carbon credit for the Teles Pires Dam is not additional because the dam had been contracted and construction begun independent of CDM funding.

The presumption that the dam would have no greenhouse-gas emissions is false, as multiple studies indicate substantial emissions from Amazonian dams over their first ten years (the time span of the project).

The regulations of the CDM are in urgent need of revision to eliminate creation of "hot air" (Certified Emissions Reductions that are not additional) through crediting of dams.

Full accounting of hydroelectric dam emissions, including methane released from water passing through the spillways and turbines, needs to be required in guidelines for national inventories and in the IPCC's comparisons of hydropower with other energy sources.

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Table 1 CDM Hydro pipeline as of 30 January 2012[a]

Country	Total projects[b]	Installed capacity (MW)	CO_2e[c] average/yr (million t)	% of total CO_2e
China	1,410	61,280	179.7	62.2
Brazil	117	8,495	17.8	6.2
Other non-Annex I[d]	774	88,577	91.4	31.6
Total	2,301	158,352	288.9	100.0

[a] Data from Chu (2012) based on the UNEP Risoe Centre (http://cdmpipeline.org/).

[b] Includes both "large" (defined by the CDM as > 15 MW) and "small" (≤ 15 MW) projects.

[c] 1 ton carbon-dioxide equivalent (CO_2e) = 1 certified emissions reduction (CER).

[d]Countries without limits on their emissions under the Kyoto Protocol.