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Bioenergy Projects and Sustainable Development: Which Project Types Offer the Greatest Benefits?

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ABSTRACT

Modern bioenergy sources are often viewed as important components of a low-carbon, energy-secure future. By reducing dependence on imported fuel and providing new employment opportunities, bioenergy production has the potential to stimulate local economies in developing countries. And yet, given the diversity of biomass resources, options, markets and scales, a better understanding of how well different bioenergy project types can provide sustainable development is needed. This analysis evaluated how the potential for sustainable development benefits differs across 12 bioenergy project types, in order to help identify which project types are best positioned to provide such benefits. It systematically examines the benefits claimed in project design documents for 76 Clean Development Mechanism (CDM) bioenergy projects in India, Brazil and Sub-Saharan Africa. The claimed sustainable-development benefits differ as widely among bioenergy project types as among all other CDM project types. Among CDM bioenergy projects, those that rely on on-farm residues claim to offer the greatest number of benefits, while those that rely on industrial forestry residues claim the fewest. Improved sustainability assessment of biomass energy project types, benefitting from on-the-ground post-implementation evaluations, is needed to guide priority-setting for international mitigation finance and CDM reform efforts.

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INTRODUCTION

Biomass energy[1] or "bioenergy" is possibly the most confounding of energy sources. It comprises a wide range of resources, options, markets and scales, from grid electricity to household fuels. Modern bioenergy sources, such as liquid biofuels, biomass-fired electricity, or methane from animal wastes, are often viewed as important components of a low-carbon, energy-secure future. By reducing dependence on expensive and imported fuel, bioenergy can stimulate local economies. In addition, in developing countries, new employment opportunities, income from the sale of agricultural residues, and infrastructure built for bioenergy projects could help reduce rural poverty, most often the extreme poverty that is the target of the Millennium Development Goals.

Global studies suggest that bioenergy demand will rise significantly by 2050. In order to cut the energy-related CO_2 emissions to half of the current levels by 2050, the International Energy Agency has suggested that bioenergy use should triple by 2050, to approximately 135 exajoule (EJ) per year (IEA 2010); projections of bioenergy potential range from 100 to 300 EJ by 2050 (Chum et al. 2011).

The role of bioenergy in supporting broader sustainability goals, however, is uncertain. Much bioenergy use today still occurs in poorer households and rural areas, and the materials are often harvested unsustainably (IEA 2010). Where new bioenergy crops are planted, they can compete with food, feed, and fiber production, and the use of crop and forestry residues can harm soil fertility (Fargione et al. 2008; Johnston et al. 2009; Rathmann et al. 2010).

The Intergovernmental Panel on Climate Change's *Special Report on Renewable Energy Sources and Climate Change Mitigation* (Chum et al. 2011) indicates that much of the increased demand for biofuels – as well as the potential for supply – will come from developing countries. Biofuel use for transportation and biomass use for power generation have both grown significantly in several developing countries, where small-scale power and heat from agricultural wastes (e.g. rice and coconut husks), as well as bagasse power, from sugar cane after extraction, are increasingly common (Alexeew et al. 2010).

Given this diversity and the wide range of potential outcomes, we believe there is a need for a better understanding of how well different bioenergy project types can foster sustainable development (SD) in developing countries. The goal of this analysis is to shed light on how these benefits vary across bioenergy projects, in order to help identify the project types with the greatest potential for sustainable development.

Bioenergy projects are supported through many different types of international programs, including those directed towards the carbon market, such as the Clean Development Mechanism (CDM), Verified Carbon Standard, or World Bank BioCarbon Fund, and those targeting a broader suite of sustainability and development benefits (Global Environment Facility, Global Village Energy Partnership, EUEI – Intelligent Energy COOPENER). We focus our comparison on CDM biomass energy projects.

The CDM, with standardized project documentation and relatively large project volume, provides a unique laboratory for examining SD dimensions of bioenergy projects. Under the Kyoto Protocol, the CDM is a flexible compliance mechanism allowing developed countries to meet a portion of their emission reduction commitment through investment in low-carbon projects in developing countries. As stated in Article 12 of the Protocol, the CDM has two objectives: to generate greenhouse gas

[1] Here we follow the United Nations Food and Agriculture Organization (Morgera et al. 2009) definition of "bioenergy" as energy generated from biofuels, where "biofuels" are fuels of renewable and biological origin, including wood fuel, charcoal, livestock manure, biogas, bio-hydrogen, bio-alcohol, microbial biomass, agricultural wastes and byproducts, and energy crops.

emission reductions, and to promote sustainable development in developing countries (United Nations 1997). There are no standard SD guidelines or requirements under the CDM, however; instead, the SD criteria are developed by the host country and evaluated on a project-by-project basis. For this study, we have developed a uniform set of measures by which to evaluate the SD benefits of CDM biomass energy projects, and rated project types by their SD potential.

Review of prior studies

Much of the current literature examining SD benefits of project-based activities has focused on whether or not the CDM is able to deliver on its dual objectives of emission reduction and sustainable development. Despite the intent to give host countries the authority to establish and control their own priorities for sustainable development, there is concern that in the competition to attract CDM investment, this approach may lead to a “race to the bottom,” where SD standards are set lower and lower to create favorable conditions for investment (Olsen 2007; Sutter and Perreno 2007). In response, several authors suggest that SD indicators should be used to evaluate whether or not a project meets the SD requirements and is approved as a CDM project.

Several papers have evaluated the potential environmental, social and economic sustainable development benefits of CDM projects with comparisons across project types and host countries (Alexeew et al. 2010; Cosbey et al. 2006; Disch 2010; Nussbaumer 2009; Olsen and Fenhann 2008; Sutter and Perreno 2007). These authors have developed SD indicators for evaluating qualitative and quantitative SD benefits of CDM projects based on project design documents. Each compares the SD benefits across CDM project types. In all cases, biomass energy projects are grouped together and compared with other project types. Overall, Olsen and Fenhann (2008) found employment benefits, followed by air quality benefits, to be the most common SD benefits of CDM projects. They also found biomass energy projects to rank below average and tend toward providing primarily socio-economic benefits, including especially corporate social responsibility benefits. Disch (2010), in comparison, using different SD indicators and a larger sample of projects, found biomass projects to have strong environmental benefits

Largely based on employment generation and improvement of local air quality, based on a relatively small set of projects, Sutter and Parreno (2007) gave biomass projects the highest SD ranking. Alexeew et al. (2010), evaluating CDM projects in India, found biomass projects, along with hydropower and wind projects, to have on average higher SD benefits and contribute to all SD dimensions. Sirohi (2007), focusing on rural poverty alleviation, found that CDM projects in India, including biomass energy projects, were aimed at business development and were not making a notable contribution toward development for the rural poor. It is not clear from these prior analyses how the mix of bioenergy project types examined may have influenced the assessment. Our aim, in building on this prior work, is to investigate how SD benefits vary across different types of bioenergy projects.

It is important to note that the approach we developed to evaluate SD focuses on the SD *potential*, not *realized* SD benefits. All of these analyses are ex-ante, of the SD potential indicated by the project design, not a verification of what actually occurred. No countries currently require that SD benefits be monitored, reported or verified, nor are SD benefits evaluated as part of the validation process;[2] in fact, realization of SD benefits is not a requirement at the national or the international level (Olsen and Fenhann 2008).

[2] With the exception of Gold Standard CDM projects.

Methods

Selection of sample bioenergy projects

CDM projects are useful for several reasons as a laboratory to explore potential sustainable-development benefits from bioenergy projects in the carbon market. CDM has the largest market volume of project-based emission reductions (Kossoy and Ambrosi 2010), thereby offering a large sample of projects, and it also provides publicly available project-related information. The Project Design Documents available online (UNFCCC n.d.) served as the primary source material for this review. We focused on a comparison of registered CDM projects from established CDM host countries with a majority of the biomass energy projects: India, with 53 percent of the registered bioenergy projects, and Brazil, with 15 percent. For comparison, we also examined registered and validation-stage CDM projects in Africa, an emerging region for CDM biomass energy projects.

We selected our sample from a database of projects in the CDM pipeline (UNEP Risoe Center 2011). As of January 2010, there were 291 registered biomass energy projects and 381 projects at the validation stage. We restricted our sample to bioenergy projects using plant-derived biomass, excluding all projects using poultry litter and industrial waste from meat processing facilities. We also focused on registered projects, though, as noted above, we also included a small set of validation-stage projects in Africa. A total of 71 registered and 5 validation-stage biomass energy projects were reviewed. The number of sample projects selected from each region and of each project type was scaled based on the proportion of projects in the full database of projects, with minor adjustments for categories with a very small number of projects.

The total number of projects in each category and the number of sampled projects is presented in Table 1. Sample projects in each category were selected randomly from the pool of projects in the corresponding category in the database. The projects were classified into 12 project types, following the categories used in the CDM pipeline database (UNEP Risoe Center 2011).

Implemented projects are not equally distributed across project types. Agricultural sector projects, both registered and at validation, predominate, making up 85 percent of projects, versus 15 percent from the forestry sector. Among agricultural projects, three types account for 76 percent of the total: agricultural residues: other, agricultural residues: rice husks, and bagasse.

Table 1. Biomass energy projects summary by total number registered, at validation and sampled, by region and resource type.

Biomass Resource Type	India *Sampled projects (number registered)*	Brazil *Sampled projects (number registered)*	Africa *Sampled projects (number registered)**	Registered Projects		At Validation Projects	
				Project Count	Annual Total k CERs (t CO_2e/yr.)	Project Count	Annual Total k CERs (t CO_2e/yr.)
Agricultural residues: mustard crop	5 (5)	-	-	5	180	5	141
Agricultural residues: other kinds	19 (52)	1 (1)	1 (0*)	85	6,806	108	9,839
Agricultural residues: rice husk	6 (46)	3 (3)	-	58	1,944	98	6,795
Bagasse Power	9 (37)37	6 (26)	3 (2*)	80	3,160	72	3,598
Biodiesel	-	-	1 (0*)	-	-	2	119
Biomass briquettes	3 (3)	-	-	3	20	9	143
Black Liquor	2 (3)	1 (1)	-	7	411	4	979
Forest biomass	-	2 (3)	-	3	92	11	1,314
Forest Residues: other	2 (2)	2 (2)	3 (2*)	9	622	16	1,291
Forest Residues: sawmill waste	-	3 (6)	1 (0*)	11	1,539	23	911
Gasification of biomass	2 (4)	0 (2)	-	6	120	8	162
Palm oil solid waste	2 (2)	-	-	24	1,957	25	1,326
Subtotal	**50 (154)**	**17 (44)**	**9 (4*)**	**291**	**16,851**	**381**	**26,617**

Note: Sampled CDM projects located in Africa were selected from registered and validation-stage projects, so for these categories, the number of sampled projects exceeds the number of registered projects. Africa projects were located in the following countries: Democratic Republic of Congo (1); Kenya (1); Senegal (2); South Africa (2); Swaziland (1); and Tanzania (2).

Source: All information is based on the CDM pipeline from Jan. 9, 2010 (UNEP Risoe Center 2011).

Evaluation of sustainable development potential

Our aim with this analysis was to provide a more detailed investigation of how SD benefits differ among biomass energy projects, building on prior studies. In order to make our results comparable to those of prior work, we used similar SD criteria. A review of the SD evaluation approaches and criteria used by authors of prior work is presented in Table 2.

Table 2. Comparison of SD criteria, scoring and weighting system in the literature.

SD Criteria	Sutter 2003	Cosbey et al. 2006	Sutter and Parreno 2007	Olsen and Fenhan n2008	Nuss-baumer 2009	Alexeew et al. 2010	Disch 2010
Approach	MATA-CDM	DD	MATA-CDM	DD	MATA-CDM	MATA-CDM	DD
Scoring	Range: 1 to -1	Total out of 100	Range: 1 to -1	yes/no scoring	Range: 1 to -1	Range: 1 to -1	Range: 1 to 0
Negative scoring	Y	N *	Y	N	Y	Y	N
Weighting of SD criteria	weighted	weighted	weighted	equal	equal	equal	equal
Environmental							
Local air pollution	●	●	●	●	●	●	●
Local water pollution/quality	●			●	●	●	●
Local soil pollution				●		●	●
Natural resource degradation	●	●		●	●		●
Waste reduction				●			●
Renewable energy source	●	●			●		●
Economic							
Employment	●	●	●	●	●	●	●
Local sourcing		●					●
Technology transfer	●	●			●	●	●
Improve public infrastructure	●				●	●	●
Energy security/access		●		●			●
Balance of payments		●				●	
Project located in poorer region	●				●	●	
IRR of project	●		●		●	●	
Sustainability tax				●			
Corporate social responsibility				●			●
Cost-efficiency of GHG abatement						●	
Social							
Stakeholder participation	●				●	●	●
Pro-poor focus		●		●		●	●
Health and safety standards/access				●		●	●
Share profits	●	●	●		●		●
Capacity building (training/education)	●	●		●	●	●	●

Note: Approaches are classified as multi-attribute assessment methodology (MATA-CDM); Development Dividend (DD). Negative points are awarded for specific types of large hydropower projects. Source: authors' review.

Several authors have developed different criteria and evaluation approaches for reviewing the potential SD benefits of CDM projects (Alexeew et al. 2010; Cosbey et al. 2006; Olsen and Fenhann 2008; Sutter and Perreno 2007; Nussbaumer 2009; Disch 2010). Most of these approaches are designed to help assess whether or not a host country should approve a proposed CDM project. They differ in the SD criteria examined, the weighting of indicators, the scoring of indicators, and the project data resources examined, as well as in the level of standardization across host countries.

A multi-criteria assessment approach, the multi-attribute assessment methodology (MATA-CDM), has been developed and applied by Sutter and Parreno (2007) and Heuberger et al. (2007). MATA-CDM uses SD criteria (developed through a stakeholder participation process in each region) and matching indicators (weighted by their SD benefits) to calculate a single sustainability rating for each project. Despite the utility of a single measure of sustainability, this approach has not been widely employed, in part because it requires a large volume of data and significant stakeholder involvement (Olsen and Fenhann 2008). Under the MATA-CDM approach, both the SD criteria and the weighting of indicators are based on an in-country stakeholder consultation process. Many studies also used additional project data, such as company surveys, to gather information on SD criteria. This information is often confidential and not included in project design documents. Use of additional project data allows for evaluation of potential negative impacts, which would not be consistently reported in project design documents.

Others have built upon work by Cosbey et al. (2006), who designed the “development dividend” (DD) framework to score projects based on a standardized set of SD criteria (Disch 2010; Alexeew et al. 2010; Olsen 2007). This approach also has limitations: by using standardized SD criteria and weighting, the evaluation may not match local/national priorities. The “development dividend” approach evaluates only the presence or absence of a contribution to the SD criteria, without further evaluation of the degree of contribution. As a result, this approach provides more insight into the scope of the SD benefits of projects, rather than how much of a SD contribution they make (Olsen 2007). Only positive contributions are evaluated by the development dividend approach, as noted by Olsen (2007), because developers are unlikely to write anything negative in their own project design documents. However, these same limitations have the benefit of allowing for a much simpler, qualitative and replicable assessment of a higher volume of projects.

For the purposes of our analysis, where the goal is to evaluate how, in aggregate, biomass energy project types differ in their potential SD benefits, not how an individual project is likely to perform, we have deemed the “development dividend” approach most appropriate.

It should be noted that our analysis is limited to evaluating SD benefits and did not include evaluation of additionality or cost-effectiveness of CDM projects. These issues are of primary concern for evaluating the effectiveness of the CDM, but not the aim of our research. Disch (2010) developed a set of SD criteria to focus on the local and community benefits of projects based on incorporating indicators from several prior studies. We used the same set of 15 indicators used by Disch, because they covered a wide range of economic, environmental and social SD criteria, and allowed us to compare the range of bioenergy projects against all CDM project types evaluated in his prior work.

The specific SD criteria and scoring guidelines we used, identical to those developed by Disch (2010), are included in Table 3. Based on the scoring system for the SD criteria presented in Table 3, we assigned each sampled project a score for each criterion. Following the evaluation approach of Olsen and Fenhann (2008) and Disch (2010), projects only received credit for the SD benefit if the project design documents included an example of how the project produces that benefit: statements such as “economic growth and social benefits will be achieved” were not considered sufficient unless examples such as “employment during the construction of the project” were provided.

In order to evaluate sample projects consistently, the scoring was based solely on review of the project design documents. No additional resources were used and no judgments were made as to whether the expected outcomes were likely to occur. Text analysis was done using the Atlas.ti Version 6.2 software (Atlas.ti GmbH 2010). Text passages used to make scoring decisions were stored using Atlas.ti. This facilitated review of scoring to ensure that projects were scored consistently. A subset of projects was scored by two analysts to compare results for consistency. Additionally, scores given to 6 projects reviewed in this analysis were compared to scores given by Disch (2010) to the same projects. There was 9 percent variation between scores given in our review and those of Disch. Despite the standardization of the scoring system, the text analysis remains a subjective determination of the benefit, and we expect that there would be variation in the judgment of different analysts.

Table 3. Development Dividend index for each biomass project type (● = >80% of projects; ○= <20% of projects).

	Biomass Resource Type	Palm oil solid waste	Gasifi-cation of biomass	Ag. residues: other kinds	Ag. residues: mustard crop	Forest Residues : other	Bagasse Power	Biomass briquettes	Biodiesel	Ag. residues: rice husk	Forest biomass	Forest Residues : sawmill waste	Black Liquor	Subtotal
	Count	2	2	21	5	7	18	3	1	9	2	4	3	77
Economic	Employment	◑	●	◕	●	◕	◑	◕	●	◑	●	○	◔	60%
	Local supply	●	◑	●	●	◕	○	●	○	◑	◑	◔	○	57%
	Technology transfer	◑	○	◔	◑	◔	◔	○	●	◔	○	◔	○	26%
	Infrastructure	○	○	○	○	◔	○	○	○	○	○	○	○	4%
	Energy security	◑	◑	◑	◕	◑	◔	○	●	◔	○	◔	◔	39%
Environmental	Air quality improve	◑	◑	◔	◑	◑	○	●	○	○	○	◔	○	29%
	Water/soil quality improve	●	◑	◑	○	○	○	○	●	◑	○	○	○	25%
	Natural resources	●	●	◑	◑	◑	◔	○	○	○	○	○	◔	32%
	Use/Avoid Waste	◑	○	●	◕	●	●	●	○	●	◑	●	◔	82%
	Renewable energy	●	●	●	●	●	●	●	●	●	●	●	●	100%
Social	Stakeholder consultation	●	●	●	●	●	●	●	●	●	●	◕	●	99%
	Pro-poor/marginal population	○	◑	○	○	○	◔	○	○	○	○	○	○	10%
	Health/safety benefits	◑	○	◔	○	◔	◔	○	○	○	○	◔	○	19%
	Share CER profits	○	◑	○	○	○	○	○	○	○	○	○	○	4%
	Educate/train	○	○	○	○	○	◔	○	○	○	○	○	○	6%
	Total	7.5	7.0	6.3	5.8	5.8	5.2	5.2	5.0	4.6	3.8	3.5	2.7	5.4
	STD DEV	2.1	2.8	1.4	1.5	1.0	1.6	0.6	0	1.2	0.4	1.1	1.3	

Table 4. Environmental, economic and social SD criteria used to evaluate projects.

SD Criteria	1 point	0.5 point	0 point	Additional Comments
Environmental				
Does the project reduce local air pollution?	Reductions of pollutant gases (e.g. SO_x) Reductions of odor nuisance (manure/landfill)	---	Complying with relevant environmental legislation not considered an improvement No points for indirect benefits (e.g. reducing pollution from grid electricity)	
Does it reduce local water or soil pollution?	Improved quality of wastewater or soil pollution from landfill sites. Only local and direct benefits considered	--	Complying with relevant legislation not considered an improvement.	Physical soil degradation addressed in third environmental criterion
Does it reduce natural resource degradation?	Active enhancement of natural resources (e.g. reforestation or enhanced benefits to biodiversity)	Activities reducing pressure on natural resources or conservation activities(e.g. reduced demand due to efficiency improvements)	No improvement/reduction in natural resource degradation	Reduction of fossil fuel consumption accounted for in fifth environmental criterion
Does it improve waste management	Both: Any contribution to utilization Avoidance/reduction of solid or liquid waste	Either: Any contribution to utilization Avoidance/reduction of solid or liquid waste	No improvement to waste management.	Pollution effects of improved waste management, as reduced leakage or odor nuisance accounted for in first and second environmental criterion
Does it 'green' the energy production?	Projects generating energy from renewable resources and therefore displacing fossil fuel use	--	No renewable energy production	
Economic				
Does the project create new employment?	Creation of direct employment, long-term jobs – must be specific (e.g. new employment for operation or maintenance)	Short-term employment for construction and commissioning phases	No new employment generated	
Does it source material or inputs from local supplies?	Generation of indirect income generation (e.g. sourcing rice husk)[3]	Inputs from local population only used during construction phase	No local sourcing of material	

[3] Although applicable, the framework for evaluating SD benefits did not directly address cost savings associated with projects (e.g. reduced cost of purchasing charcoal in the case of a domestic biogas project).

How does it initiate technology transfer?	Technology development and improvement by adapting technologies to unproven circumstances Emphasis on introducing new technology to the region/country No judgment made on whether transfer from within or outside the country is better.		No new technology transfer	
Does it extend public infrastructure?	Building or extending public infrastructure (e.g. roads, extension of electricity grid, community halls, new or improved landfills etc.)	--	No extension of public infrastructure	
Does it contribute to the energy security of the country?	Both: Increased reliability of the grid (e.g. continued fuel supply or counteracting undersupply) Increased access to energy through increased coverage and availability of electricity or heating services (e.g. solar lighting systems, grid extension to previously unelectrified areas	Either: Increased reliability of the grid (e.g. continued fuel supply or counteracting undersupply) Increased access to energy through increased coverage and availability of electricity or heating services (e.g. solar lighting systems, grid extension to previously unelectrified areas	Neither	
Social				
How did the project involve local stakeholders?	Both: Identification of stakeholders Open public meetings (as opposed to letter or email communication or surveys only)	Either: Identification of stakeholders Open public meetings (as opposed to letter or email communication or surveys only)	Neither	
Does it have a clear focus on rural and/or poor?	If project is clearly targeted at marginalized populations or communities	Side benefits to rural development and poverty alleviation (e.g. providing a local farmer co-operative with free electricity)	--	
Does it contribute to health and safety standards?	Reduction of health risks (e.g. reduced fire hazards or the provision of additional health care activities)	--	Indirect claims not considered (e.g. hydropower plan cannot claim health benefits from replacing a coal-fired power plant)	

Does it share some of the profits?	Parts of CER revenues are shared with local communities or the regional or national government in the form of donations	--	Profits are not shared	
Does it provide training and education?	Facilitation of training and education (e.g. education programs, building schools) beyond the capacity development of the project itself	--	Capacity development to make the CDM project possible and the technology work is not included as it will be needed to some degree in all projects and a qualitative distinction is not possible	

Note: Questions and scoring are from Disch (2010).

RESULTS

The average number of claimed SD benefits identified from our review of 77 biomass energy CDM project documents corresponds to the review of biomass energy projects from Disch (2010). Both studies found biomass projects, on average, claimed the potential for 5 SD benefits. Our review found individual biomass energy project documents ranged from claiming as few as 1.5 SD benefits to as many as 9.5. The most common SD benefits claimed by project documents were renewable energy production (100 percent), stakeholder identification (99 percent), waste reduction (82 percent), employment generation (60 percent), and indirect income generation through local sourcing of feedstock (57 percent). While the first two claimed SD benefits are implicit for biomass energy CDM projects, as the use of renewable biomass and stakeholder involvement are required under CDM rules,[4] the third is implicit for all biomass residue projects. Most biomass project documents claim SD benefits from economic and environmental criteria, with very few social benefits beyond stakeholder participation. About a quarter of the projects sampled claimed the potential SD benefits of technology transfer, energy security, reduction of natural resource degradation or improvement of air or water/soil quality. Far fewer projects cited benefits from improved infrastructure, training/education, improved health/safety standards, or carbon credit profit-sharing, and few had a clear rural or poverty-reduction focus.

Biomass energy projects, as shown in Table 4, varied in the range of potential SD benefits across project types, as well as among individual projects of the same type. Black liquor (a liquid by-product of processing wood pulp for paper), forest biomass, and forest residues: sawmill waste projects consistently claimed the fewest number of SD benefits. These project types were also less likely to claim to provide the SD benefits common to other projects reviewed. None of the black liquor projects, which were primarily projects designed to upgrade existing boiler equipment, claimed to provide indirect income through local supply of biomass or any social SD benefits beyond stakeholder identification. Only 1 out of 3 black liquor projects claimed to provide either direct employment or improved energy security – SD benefits claimed for several other project types. Although all of the forest residues from sawmill waste projects claimed to provide waste reduction, none of the projects provided new direct employment with the addition of the CDM project. Forest biomass projects, one sourced from a eucalyptus plantation and the other from charcoal production residues, both claimed to

[4] Although required, one project reviewed did not include evidence of stakeholder identification.

provide direct employment. However, both projects were less likely to provide other economic and environmental SD benefits found in other projects.

The vast majority of agricultural residue: mustard crop, agricultural residues: other, and palm oil solid waste projects (more than 80 percent) claimed an above-average number of SD benefits. These projects all provided income to the local community via local sourcing of biomass, though individuals are not directly employed by the project. Many of these projects also claimed SD benefits from direct employment, technology transfer, energy security, improvement of air/water/soil quality, and reduction of natural resource degradation. These claimed SD benefits are surprising given critiques of palm oil projects, especially related to land-use change emissions from forest clearing. Though these CDM projects are only dealing with the waste management portion (and not the forest clearing) of the projects, providing financial benefits to enterprises that might otherwise have negative impacts raises some questions about indirect project impacts.

There were three projects that claimed more than 9 SD benefits each, many more than the average for all biomass projects. All three were in India, in three categories: agricultural residues: other, palm oil solid waste, and gasification of biomass. All claimed to produce direct employment, indirect income from local supply of biomass, and improved energy security SD benefits. At least 2 of the 3 projects claimed to provide each of these SD benefits: technology transfer, air and water/soil quality improvement, reduction in natural resource degradation, waste reduction, and health/safety improvements.

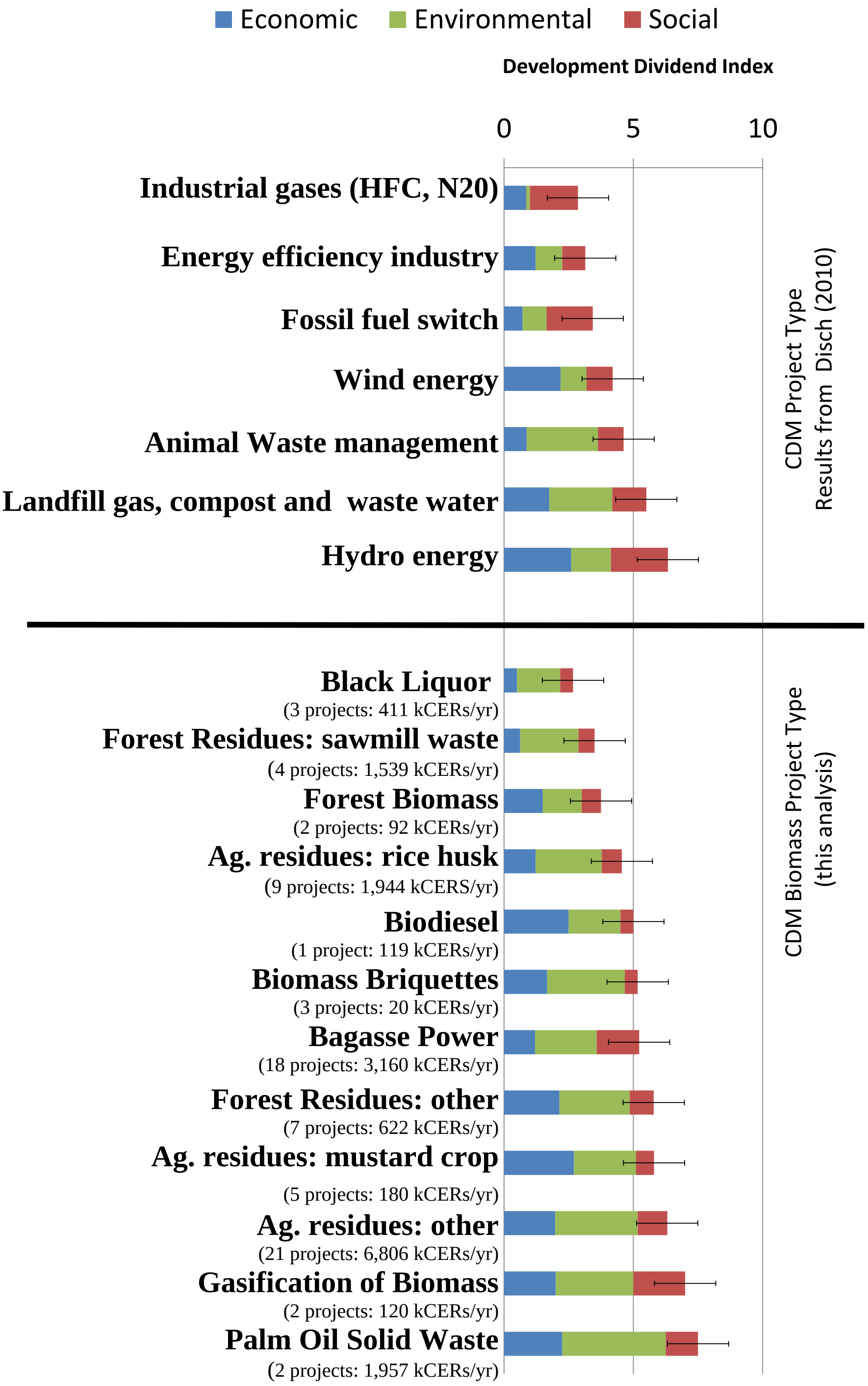
The gasification of biomass project, a small-scale project to install 100 village biomass gasification decentralized energy systems, stands out for its focus on sustainable development for the poor. Energy generated will replace existing diesel generators, both reducing local air pollution and extending energy services to more households and for use in micro-industries and for water pumping. The design document claims that the project was recognized by the World Bank and declared a 2006 Development Marketplace winner.

The palm oil waste project is a small-scale, grid-connected electrical generation facility. In addition to direct employment, it claims to provide indirect income generation to farmers for collecting residues, and to be the first project of this kind in the region. The project document claims that use of palm oil waste improves air quality by reducing the current practice of open burning and current water contamination issues from decaying waste material. The developers also say they will provide specific health and safety equipment to employees and will use treated waste water to promote development of a green belt surrounding the facility.

The agricultural residue project is a 16MW cogeneration grid-connected facility designed to produce heat for the existing tire manufacturing facility and provide electricity for sale to the grid using low-density residues, claimed to be an innovation for electricity generation. In addition to providing direct employment (an estimated 800 jobs) and indirect income for residue collection, the project claims to improve air quality by reducing open burning, and to improve water quality by reducing ground water contamination from wastes. The project claims to provide additional benefits of encouragement of organic farming by providing ash residue as organic fertilizer and management of occupational health and safety. Bagasse projects showed the widest variation in the range of claimed SD benefits, from 3 to 8.5 claimed SD benefits. While only half provide direct employment and less than 15 percent provide opportunities for indirect income, bagasse projects stood out amongst other projects for claiming to provide many more social SD benefits, including having a focus on the poor, health/safety benefits, and education/training opportunities. This distinction of bagasse projects claiming to provide several corporate social responsibility benefits was also noted in the evaluation by Olsen and Fenhann (2008). These social SD benefit claims are particularly prevalent for bagasse projects in Brazil, where at least half of the projects claim to focus on the poor, as well as offer health/safety and education/training opportunities for their employees and the local community. Some of these projects claim to operate and provide secondary school classes, as well as to operate health clinics. While, as for all of the SD claims made by projects, it is not possible to determine whether these benefits are realized, for these projects it is also difficult to determine whether these benefits can really be attributed to the CDM project. All of the bagasse projects involve existing sugar cane processing facilities, where a new high-efficiency boiler is being installed to process sugar cane residues. The project documents do not clarify how or whether these social benefits are being produced through the CDM project, or whether they were already been in place as part of the sugar cane mill operations.

Using the same SD criteria as Disch (2010), we are able to compare results from our analysis of specific bioenergy project types across the wider range of CDM project types evaluated in Disch's analysis, as shown in Figure 1. A majority of the biomass energy projects we examined claim to provide more SD benefits than many other CDM project types. These biomass energy projects are shown to claim a similar number of potential SD benefits as landfill gas and hydro energy projects examined by Disch. Black liquor projects notably fall below industrial gas projects in the number of claimed SD benefits. Forest biomass and forest residue: sawmill waste, as discussed above, also fall below other biomass energy projects, more closely resembling fossil fuel switch and wind energy projects in the number of claimed SD benefits. This comparison across CDM projects suggests that certain biomass energy projects can be among the highest-performing projects in terms of the number of SD benefits delivered. At the same time, certain types of biomass energy projects can be among the worst performers in delivering SD benefits.

Figure 1. SD benefits across project types.

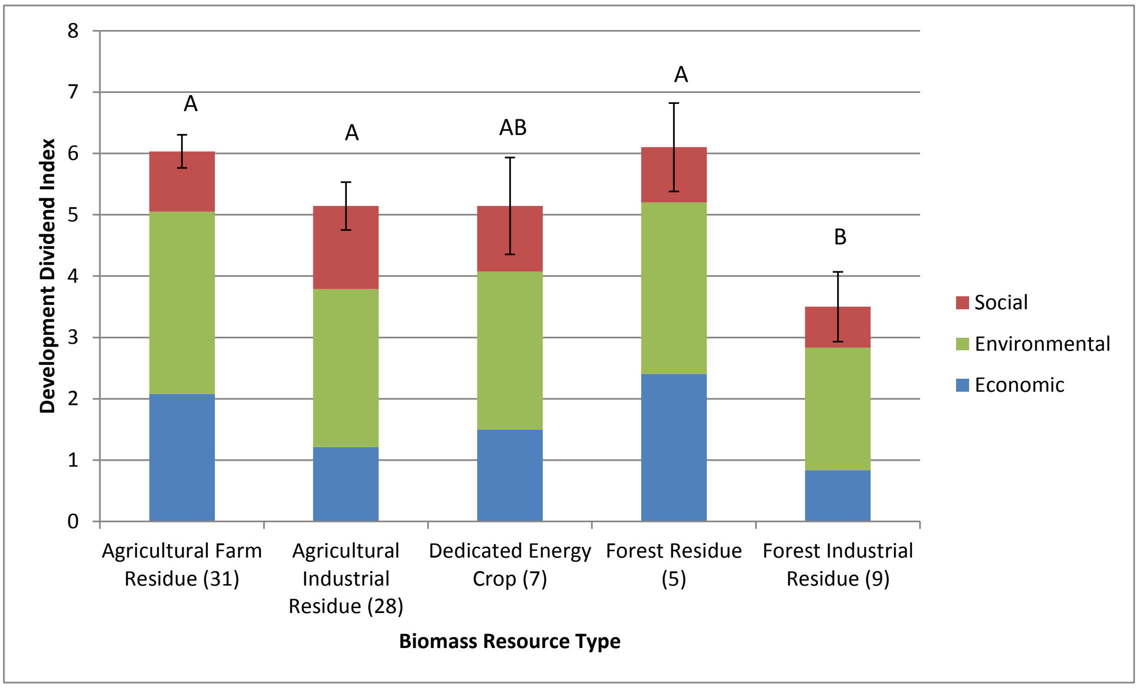


Note: Number of claimed economic, environmental and social SD criteria and ±1 standard deviation are shown for each project type. Results for specific biomass energy projects are from this analysis. Results for other CDM project types are from results in Disch *(2010)*. Number of biomass projects indicates the number of projects sampled in this study. The number of kCERs/yr is the total number of *kCERs/yr for all registered projects of that project type in the CDM pipeline (UNEP Risoe Center 2011).*

Based on these initial observations across biomass project types, we notice that projects sourced from on-farm (non-industrial) residues (e.g. mustard crop, other) tend to claim more SD benefits than projects using industrial residue sources (e.g. sugar cane, rice husks, sawmill and paper mill wastes). There are several potential explanations for this. Industrial residue sources most often do not provide indirect income from gathering of field residues, since they are already available on-site from the existing industrial process (e.g. sugar cane waste for bagasse or sawmill residues). Also, projects that use industrial residues were more often existing facilities that used the new biomass energy on-site, rather than supplying the grid, so they did not make the same contribution to energy security, and they often did not provide additional employment, but rather reassigned existing workers.

We investigated these trends further by grouping project types by sector agricultural, forest, dedicated energy crop, and whether or not the residues are from an industrial source, as shown in Figure 2. Further statistical analysis shows that forest projects using industrial residues sources, including black liquor and sawmill residue projects, claimed to provide statistically significantly fewer SD benefits than projects from other residue sources ($p<0.000$). However, dedicated energy crop projects, perhaps as a result of the smaller sample size and larger standard error for this type, were not found to claim significantly more SD benefits than forest industrial residue projects. Agricultural residue projects, from both industrial (bagasse, rice husk, palm oil) and non-industrial (mustard crop, other kinds), as well as forest non-industrial residues, had significantly more potential SD benefits than forest industrial residue projects.

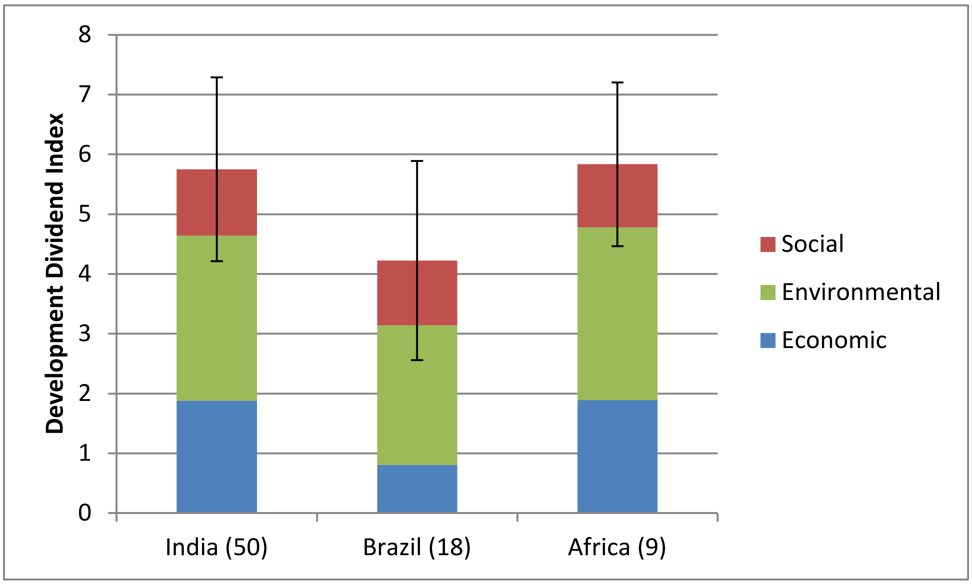
Figure 2. 'Development dividend' index by biomass resource type.



Note: Biomass resource type mean values were compared with ANOVA and Tukey multiple comparisons test. Mean values with notation with different letters "A" vs. "B" are statistically significantly different at the $p<0.000$ level. Biomass resource type mean values with the same letters "A" and "AB" are not statistically significantly different. Error bars represent ±1 standard error.

We were also interested in examining how potential SD benefits varied by region, as shown in Figure 3. A preliminary statistical analysis indicated that the SD benefits do vary significantly by region ($p<0.01$). The number of potential SD benefits claimed from projects in both India and Africa were significantly greater than in Brazil. However, we recognized that the make-up of project types across these three regions was not evenly distributed. Many more of the sampled Brazilian projects are generated from industrial residues (72 percent), compared with only 35 percent in India; for comparison, 60 percent of projects in Africa are generated from industrial residues. This suggests that the significant variation across regions may be a result of a variation in the distribution of project types across the regions, rather than any regional characteristic.

Figure 3. 'Development dividend' index by region.



Note: Figure shows the number of claimed SD benefits for economic, environmental and social criteria, with one standard deviation indicating the range. The number of projects sampled from each region is indicated in parentheses.

CONCLUSIONS

Our results confirm that the claimed number and range of SD benefits varies significantly by biomass energy project type. To the extent that SD benefits reported in project documents are likely to be good predictors of project performance, several bioenergy project types appear to offer significantly greater SD benefits than most CDM project types. The range of claimed SD benefits across bioenergy project types is as large as across all CDM project types examined. On-farm residue projects, including the agricultural residues from mustard crop and other sources, claimed to provide the largest number of SD benefits. These projects tended to claim to have the potential to generate direct and indirect employment, technology transfer, and environmental benefits. At the other end of the spectrum, forest projects using industrial residues, including black liquor and forest residues from sawmill waste, appear to offer no more SD benefits than industrial gas (HFC,N_2O), industrial energy efficiency, or fossil fuel switch CDM projects. These forest industrial-residue projects were less likely to provide direct and indirect employment, environmental improvement or social benefits.

Bioenergy's SD potential in the world's poorest communities

With the shifting focus of the CDM to prioritize projects in under-represented regions, especially least-developed countries and regions in Africa, there could be expanded interest in bioenergy projects for less-developed regions with primarily agricultural economies. Our results suggest bioenergy projects that exhibit certain characteristics have particularly great potential for economic and environmental SD benefits. On-farm residue projects, in particular, consistently claimed to provide new opportunities for indirect income generation from gathering/collection of residues. Supplemental income generation in rural areas in India has been identified as a key need for reducing extreme poverty (Sirohi 2007). The primary environmental SD benefits of bioenergy projects appear to occur in cases where residues currently present an air quality concern (due to open burning) or a water/soil contamination problem, so the use of wastes can reduce these pollution sources.

However, other potential SD benefits that might be expected from bioenergy were not found in this review of projects. As a decentralized fuel source, bioenergy has been considered a potentially good fit for improving rural energy access, but in our review, only one project, the one to install 100 village gasifiers in India, claimed to improve energy access. Most projects generate energy for on-site facility needs or to supply the national grid. Many grid-connected projects and even on-site use projects claim to improve energy security by improving supply (or reducing grid demand). While these electricity projects may contribute to improved energy access by improving supply, it is not possible to evaluate the validity of those claims based on the project documents. Furthermore, it has been noted that while facilities may claim that reducing grid demand by switching to on-site generation may improve energy security, for the region it may actually produce the opposite effect by reducing the stable customer base for electric utilities and thus creating instability in the emerging electric sector (Haya et al. 2009).

The food vs. fuel conundrum

While the discussion globally around bioenergy has focused primarily on liquid biofuels production, there are very few registered or at-validation biofuel CDM projects. In the regions we examined, there was only one liquid biofuel project, a biodiesel project from jatropha plantations located in the Democratic Republic of Congo.

Furthermore, much of the concern globally around bioenergy expansion has focused on the competition amongst biomass resources for food, feed, fuel and fiber, a concern most prevalent for dedicated energy crops. Increased global demand for bioenergy is expected to rely most heavily on dedicated energy crop production (Chum et al. 2011). Most CDM bioenergy projects in the regions examined rely on biomass residues, however; only 7 of the projects examined here use dedicated energy crops. Thus, given the limited sample of energy crop projects available, our study results cannot provide as much insight into the potential SD benefits of energy crop projects.

While projects relying on biomass residues may avoid some of the direct competition with food, feed and fiber production, the limited data in project design documents makes it impossible to gauge the potential negative SD impacts of projects, including the impact of residue collection from fields and forested areas. For example, in Thailand, diversion of rice husks to biomass power facilities has limited their availability to local rice farmers who previously generated natural fertilizer by mixing the residues with chicken manure (Gilbertson 2009). No distinction is made as to whether residues are removed at a rate that diminishes soil nutrients or water retention. Thus, an evaluation based on review of project documents alone cannot effectively evaluate the environmental sustainability of bioenergy projects.

Focusing on projects with greatest SD potential

Based on the distribution of registered and at validation bioenergy projects in the CDM pipeline, the project types we have identified as claiming the largest number of SD benefits already make up a majority of projects. Agricultural residue projects already account for close to 85 percent of registered bioenergy projects and resulting emission reduction credits, and the same pattern holds in the projects at validation. Black liquor and forest residues from sawmill waste projects only make up 6 percent of the projects and 11 percent of the credits for registered projects, and even less for at-validation projects. This might suggest that bioenergy project types offering the potential for a wider range of SD benefits are already being prioritized under the CDM. However, we are faced with the limitation that a review of the range of claimed SD benefits of bioenergy projects may or may not be a good predictor of the SD benefits that are realized.

This research has shed light on the differences in characteristics of bioenergy project types that may be better positioned to offer SD benefits. When bioenergy projects have been grouped together and evaluated, as done in prior studies, they have fallen out somewhere in the middle of the range of CDM projects. Here, using the same evaluation tool, but separated by different types of bioenergy projects, the claimed SD benefits vary as much as across the full spectrum of CDM projects. This level of variation across project types, based on a review of the project documentation alone, suggests that further inspection of individual projects on the ground is likely to result in even greater variation in claimed and observed SD benefits.

Moving forward

On-site review of projects has demonstrated that claimed SD benefits are not always delivered upon, and negative impacts not mentioned in project documentation can be present (Gilbertson 2009; Haya et al. 2009). The clear next step is to move from the project documentation to the project site to confirm whether the potential SD benefits of bioenergy projects are being delivered. Further on-site review could allow consideration of negative impacts of projects (e.g. is the project a new source of pollution), long-term support requirements to maintain projects after CDM revenues have terminated, as well as consideration of the cost-effectiveness of CDM emission reductions.

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