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An assessment of the Clean Development Mechanism (CDM) potential in Pakistan's Industrial sugar sector

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Abstract

Sugar product is an important industry in Pakistan and contributes 1.9% to the GDP. However, the sugar industry is emitting a number of gaseous pollutants through inefficient burning of bagasse and polluting the environment with the release of high wastewater amount. To mitigate this problem in such industries, the Clean Development Mechanism (CDM) is introduced by which highly renewable energy efficient technologies are employed. This study was conducted to find out the potential of the CDM in the industrial sugar sector of Pakistan. Two models of bagasse and biogas utilization in sugar industry were used to estimate electricity generation and carbon reduction. The results show that the sugar industry of Pakistan had the potential of 2,033MW of electricity production and 232,5968t CO_2 eq of Certified Emission Reduction (CER) annually. Certification processes were the major barriers in the implementation of the CDM in the sugar industry.

Keywords: Waste management; industrial ecology; bagasse; biogas; electricity generation

1. Introduction

Industries, like agricultural processing, cause a number of environmental problems, including air pollution, water pollution, soil contamination and groundwater contamination (Al-Senafy *et al*., 2011; Omar *et al*., 2006; Afroz *et al*., 2003; Mohammad *et al.,* 2016). The Clean Development Mechanism (CDM) is defined in Article 12 of the Kyoto Protocol. Developed countries must commit to the implement of an emission-reduction project in a developing country. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one ton of CO_2, which can be counted towards meeting Kyoto targets (Kokkaew& Sampim, 2014).

The CDM involves an arrangement under the Kyoto Protocol, and it constitutes the main means by which developing countries can be involved in the carbon market. It has two main aims: 1) Developed countries can meet their emission reduction commitments by emission reduction projects in developing countries. 2) Developing countries can cultivate projects that reduce greenhouse gas emissions and contribute towards sustainable development (Duic *et al*., 2003).

Pakistan set up its tools of agreement within the Kyoto Protocol on January 11, 2005 and later became eligible to acquire the benefits from the CDM. To mitigate the process, the Ministry of the Environment was declared the Designated National Authority (DNA). A department for the CDM was established in August 2005. This governing body provides policy and technical support, implements he CDM strategy, conducts awareness campaigns, improves the CDM project development capability, and reviews CDM projects for approval by the DNA. In addition, the department provides the guidelines to the government in technical matters related to this mechanism in Pakistan (NOS, 2006).

Any proposed CDM project has to follow approved baseline and monitoring methodology, and it has to be validated, approved and registered. The CDM project cycles involve different stages as shown in Fig. 1 (Mcnish *et al.,* 2009). A project activity must undergo these stages before it may be issued a CERs.

The first step is the identification of the project in which developers describe the project, its duration and associated impacts. It is presented in the form of a Project Design Document (PDD). The next step is host country approval, which involves receiving the letter of approval from the DNA. During the validation and registration of the project, the Designated Operational Entity (DOE) ensures that the project meets all the criteria of the CDM. After validation, the CDM project is registered. Monitoring is the phase in which the emissions reduction by the project is calculated. Then the DOE verifies the emission reduction actually achieved by the project. In the last phase, the CER is issued by the CDM executive board.

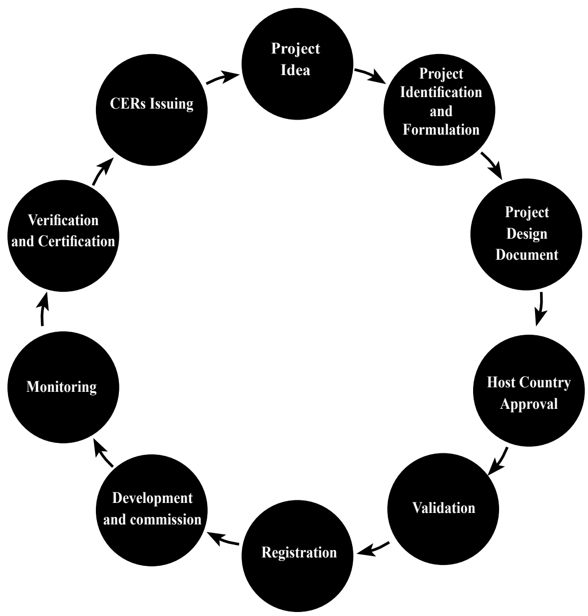

Fig. 1. CDM Project Cycle

The CDM is an excellent mechanism to secure funding for low-carbon development scenarios in Pakistan. It is an easy way to implement clean energy and renewable energy projects. There are almost 20 projects in Pakistan which have been approved by the DNA, and 29 projects are currently in the DOE pipeline. There is a need to realize the full potential of the carbon market with energy efficient projects in Pakistan (NEEDS, 2014).

Pakistan is among the larger sugar cane producing countries. According to the Pakistan Sugar Mill Association (PSMA), Pakistan ranks 7^{th} n sugarcane production and 15^{th} in the production of sugar. A large area in the country is dedicated to growing sugarcane, which is used as the raw material in Pakistan's sugar industry. There are 84 sugar mills in Pakistan (44 in Punjab, 7 in Khyber Pakhtunkhwa, and 32 in the province of Sindh (PSMA, 2011)).The byproduct of sugar industry are bagasse, filter cake and molasses. These can be used for different purposes such as electricity generation and ethanol production and can be sold as a product (Shafiq, 2011).

Two sugar processing plants, namely *Shakerganj* and *Almoiz*, have two registered CDM projects and five projects are in the validation stage (DOE, 2011). The wastes from the sugar mills (bagasse and wastewater) can be utilized as a raw material for energy-efficient projects. Thus, they contribute towards achieving CDM goals. This study basically investigates the potential of the CDM projects in the sugar industry of Pakistan. The goal is to measure electrical generation and CO_2emission reduction using two models: bagasse cogeneration and biogas utilization. The objective is to quantify the scope and potential of CDM in the industry.

2. Methodology

2.1. Data collection

Data for the current study was collected by secondary sources. The secondary sources included DOE pipeline, the Project Design Document (PDD) and annual reports of PSMA.

2.2. Preparation of models for estimation of the potential of carbon emissions and electricity generation

Two different models using the PDD's and relevant data from reports were prepared in which the waste of sugar industry had been seen with its full potential of electricity generation and reduction in CO_2emission.

2.3. Model 1: Bagasse

The ACM0002 and ACM0006 methodologies were applied for this model. Two scenarios were discussed. The first can be considered the reference case (baseline). The second scenario is after the project activity (CDM-PDD, 2006) as discussed in project emissions section.

2.3.1. Baseline scenario

In general, the most common practice in a sugar mill is the use of a 23-bar boiler pressure and turbo generator using 350ºC for meeting the demands of the sugar mill itself. This is set as the reference plant. Power is generated in a grid in the absence of the project activity. The other scenario is the installation of the biomass residue plant that uses the same quantity of biomass as the project activity, but with a lower efficiency of electricity production. The heat is generated using the same amount of biomass but with less effieicncy.. The same amount of biomass residue is used for heat and electricity generation.

2.3.2. Project emissions

A green field grid has been installed in Almoiz Sugar Mill. For this project, 27MW of electricity is generated. It uses 288,000 tons of bagasse per year. The biofuel is used in two high pressure boilers from which steam goes to the turbines, ultimately producing electricity. The project's life time is expected to be 21 years with a crediting period of almost 7 years. The annual cane crushed in the factory is 665,122 tons.

2.3.3. Derivation for emission reduction

The project's goal is the replacement of fossil fuels with biomass residue for power generation (CDM-PDD, 2006). This gives Equation (1) as follows:

$$ER(y) = ER\ (heat,\ y) + ER\ (electricity,\ y) + BE\ (biomass,\ y) - PE(y) - LE(y) \qquad (1)$$

Where ER(y) is the emissions reductions by the project over the year (y) as (tCO_2/yr). ER (heat, y) is emission reductions for the year (y) due to the displacement of heat (tCO_2/yr). ER(electricity,y) is emission reductions for the year (y) due to the displacement of electricity(tCO_2/yr). BE(biomass,y) is baseline emissions due to the natural decay or burning of anthropogenic sources of biomass residues during the year (y) as (tCO_2e/yr). PE(y) is the project emissions for the year (y) as (tCO_2/yr).L(y) is leakage emissions for the year (y) as (tCO_2/yr), and PE (y) is the project emissions.

Since there is no transportation of biomass residue to the project site, usage of fossil fuels and electricity are zero. Methane emissions are negligible on the project site. In addition, ER, heat is zero because the thermal efficiency of the project boilers is much greater than that of the exiting one. baseline emissions, BE (Biomass, y), are zero because no biomass residue is burned during the process. Thus,

ER(y) = ER(electricity, y),

where ER(electricity, y)=EG(y) × EF(electricity,y).

In this equation, EG(y) is the net quantity of increased electricity from the project in the year (y) in MWh, and EF(electricity, y) is the CO_2emission factor. Therefore,

EF (electricity, y) = EF(grid,y),

where EF(grid,y) is 0.4902.

2.4. Model 2: Biogas

The methodology used in this model is AMS-I.C. (CDM-SSC-PDD, 2006).

2.4.1. Baseline scenario

The historical data of the sugar mill shows that electricity and steam demands were collected by the existing system. A small amount of electricity is imported from the government power grid. The existing system consumes bagasse, biogas, and natural gas inefficiently. Baseline emissions are calculated by using displacement and supply of electricity with respect to grid.

2.4.2. Project scenario

The project replaces the fossil fuel with biogas to achieve emission reduction. During ethanol production, biogas is generated from the wastewater.

2.4.3. Derivation for emission reduction

Equation (2) can be written as

ER(y) = BE (y) – PE (y) – LE (y) (2)

where PE (project emissions)(y) and leakage emissions LE (y) are zero.

Baseline emissions can be determined as

BE(y) = EE (Net, Pj, Y) x EF (Grid, y)

Where EE (Net, PJ, Y) is net electricity exported to the grid by project activity in the year (y) of the crediting period in MWh/year. EF(Grid, y) is equal to 0.48290 tCO_2/MWh. So, EE (Net, PJ, Y) becomes:

EE (Net, PJ, Y) = EE (Grid, PJ, Y) – EI (PJ, Y) – EI (industry, PJ, Y)

EE (Grid, PJ, Y) is the total electricity exported to the grid by project activity through the year(y) of the crediting period in MWh/yr.EI (PJ, Y) is the electricity imported from the grid by the project activity during the year (y)of the crediting period in MWh/year.EI (Industry, PJ, Y) is electricity imported from the grid by the mill in the year (y) of the crediting period in MWh/year.

EE (Net, PJ, y) = EE (Grid, PJ, Y) – EI (PJ, Y) – EI (industry, PJ, Y)

In the above equation, EE (Grid, PJ, Y) is equal to 42,705 MWh/year, EI (PJ, Y) is equal to 0 MWh/year and EI (industry, PJ, Y) is equal to 3,973 MWh / year. This results in

EE (Net, PJ, Y) = 42,705 – 3,973 – 0 = 38,732 MWh /year

As, ER (Y) = BE (Y)

BE(Y) = EE (Net, PJ, Y) x EF (Grid, y)

= 38,732 MWh / yr x 0.48290 tCO_2/MWh

= 18,703 tCO_2 /year

3. Results and discussion

3.1. Calculation of emission reduction

The emission reduction for the first crediting period by using bagasse (Model 1) and biogas (Model 2) were calculated.

The net annual electricity exported to the grid is 38,732 MWh/year. The grid emission factor calculated in this case is taken as 0.489 tCO_2/MWh. The baseline emission was obtained by multiplying net electricity exported to grid and the grid emission factor (Table 1).

Table 1. Emission reduction by bagasse in Almoiz Sugar Mill (Model 1)

Crediting Period/ Year	Electricity Production by project (MW/h)	Electricity Production by Reference Plant (MWh)	EG(y) (MWh)	EF(grid,y) (tCO_2/MWh)	Emission Reductions =EG(y)X EF(grid,y) (tCO_2)
2009	32,426	16,569	15,857	0.490	7773
2010	97,277	49,706	47,572	0.490	23,319
2011	97,277	49,706	47,572	0.490	23,319
2012	97,277	49,706	47,572	0.490	23,319
2013	97,277	49,706	47,572	0.490	23,319
2014	97,277	49,706	47,572	0.490	23,319
2015	97,277	49,706	47,572	0.490	23,319
2016	64,852	33,137	31,714	0.490	15,546

Table 2. Calculation of emission reduction by biogas in Shakerganj Sugar Mill (Model 2)

Year	Net Electricity Exported to Grid by Project, $EE_{(Net, PJ, Y)}$ (MWh)	Emission Factor, $EF_{(Grid, y)}$ (tCO_2/MWh)	Baseline Emissions in $EE_{(Net, PJ, Y)} \times EF_{(Grid, y)}$ (tCO_2e)	EmissionReductions $ER_{(Y)} = BE_{(Y)}$ (tCO_2e)
Year 1	38732	0.4829	18,703	18703
Year 2	38732	0.4829	18,703	18703
Year 3	38732	0.4829	18,703	18703
Year 4	38732	0.4829	18,703	18703
Year 5	38732	0.4829	18,703	18703
Year 6	38732	0.4829	18,703	18703
Year 7	38732	0.4829	18,703	18703
Year 8	38732	0.4829	18,703	18703
Year 9	38732	0.4829	18,703	18703
Year 10	38732	0.4829	18,703	18703
Total	387320		187030	187030

The emission reduction for the biogas model is equal to the baseline emission which is 18,703tCO_2eq per year as shown in Table 2.

3.2 Estimation of electricity generation and CER Potential

The results for the potential of electricity generation by Model1are obtained by the annual amount of sugar cane that is crushed for processing in three provinces. Applying this bagasse model to the annual cane crushed, the potential of electricity generation can be estimated at1,132 MW, 96MW, and 552 MW for the sugar industry of Punjab, KPK and Sindh, respectively.

As shown in Table 3, the annual CER potential per year is estimated as 977,670 tCO_2, 82,912 tCO_2, and 476,744 tCO_2 for the sugar mills of Punjab, KPK and Sindh, respectively.

Table 3. Estimation of electricity potential and carbon reduction by bagasse in Pakistan's sugar industry

Sr. No.	Province	Annual Cane Crushed (tonnes)	Bagasse	
			Electricity Generation (MW)	CER Potential (t CO_2-e)
1	Punjab	27,890,459	1,132	977,670
2	KPK	2,730,338	96	82,912
3	Sindh	13,600,800	552	476,744
	Total	43,861,597	1,780	153,733

Table 4 shows data for Model 2. By applying Model 2 the electricity generation potential was calculated at 157, 17, and 79 MW for Punjab, KPK, and Sindh, respectively. Similarly, the CER potential was estimated as 489,395, 52,991 and 246,256 tCO_2 for Punjab, KPK, and Sindh, respectively.

Table 4. Estimation of electricity potential and carbon reduction by biogas in Pakistan's sugar industry

Sr. No.	Province	Annual Cane Crushed (tonnes)	Bagasse	
			Electricity Generation (MW)	CER Potential (t CO_2)
1	Punjab	26,869,460	157	489,395
2	KPK	3,035,460	17	52,991
3	Sindh	13,600,800	79	246,256
Total		46,505,720	253	788,642

4. Conclusion

The sugar industry of Pakistan has a history of high electricity consumption and excessive waste. Under the umbrella of CDM, there is a vast potential for environmentally-friendly electricity generation and CO_2 mitigation. Application of CDM has the potential to reduce these by simple changes to existing mill technology. In addition, biomass-based cogeneration projects and biogas-based projects in the sugar industry can provide a large amount of electricity and increase profits through earned carbon credits. The potential could reach up to 2,033 MW for electrical production and 232,5968 tCO_2eq for CER. By lowering hurdles and introducing more supportive policies and awareness programs, CDM could be even more beneficial.

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تقييم لآلية التطوير النظيف (CDM) في قطاع صناعة السكر في باكستان

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الملخص

تُعتبر صناعة السكر من أهم القطاعات الصناعية في باكستان وتساهم بنسبة 1.9 % من الدخل القومي للدولة. وينتج عن صناعة السكر ليس فقط انبعاثات غازية ملوثة نتيجة لعملية الحرق غير الناجعة لتفل قصب السكر ولكن أيضاً تلوث بيئي نتيجة لإطلاق كميات كبيرة من مياه الصرف. ولتخفيف هذه المشكلة، تم تقديم آلية تطوير نظيفة تتضمن تقنيات عالية الكفاءة للطاقة المتجددة للاستخدام في هذه الصناعات. تم عمل هذه الدراسة للتعرف على إمكانية استخدام هذه الطرق في قطاع صناعة السكر في باكستان. تم إعداد نموذجين لاستخدام تفل قصب السكر والغاز الحيوي في صناعات السكر لتقدير الكهرباء المُوَلدة وتقليل الكربون. كشفت النتائج أن صناعات السكر في باكستان لديها القدرة على إنتاج 2033 ميغاواط من الكهرباء وخفض الانبعاثات المعتمدة (CER) من الكربون المكافئ CO_2eq بمقدار 232,5968 طن سنوياً.إن عمليات التوثيق والتكلفة العالية للاستثمار هما العقبتين الرئيسيتين لاستخدام الآلية النظيفة في صناعات السكر.