Economic and Environmental Benefits of Cleaner Technology in Industrial Pollution Control: Case Study of Select Sugar Industry in Tamil Nadu

X. Agnello J. Naveen, S. Boopathi, A. Arivoli, and A. Kannan

Abstract Sugar industry pollutes air, water and soil that different types of advanced pollution control technologies were used to reduce the pollution levels to permissible limits. But still Sugar industry manages to recycle and reuse its by-products based on the "concept of industrial ecology" on its own production premises in a holistic positive environmental management approach. Due to the production totally based on agricultural products using "biomass", which is organic from the starting till the end of the product, there is a total life cycle assessment (LCA). Recycling of products like water recycling in a closed loop water saving system, molasses reuse, Co-generation (energy conservation), variable frequency drives (VFD), cane cutting, bagasse, press muds, composting using sludge are few methods followed in this unit. Sugar industry cost variables Economic and environmental variables, older (Conventional) and newer (Cleaner) technology and their negative and positive advantages were compared. Variables like capital cost, variable cost, viability period of the equipment, depreciation cost, buy back cost, benefit cost and environmental benefits like energy in (kWh) per year, water in liters per year and other recycling process like "Add-on" and "Process change" technologies are taken in consideration. The main objective is to focus on the cost aspects between the two technologies, conventional and cleaner technology in pollution control. This was carried out by comparing cost benefit analysis and Return on Investment (ROI) for the old and clean technologies. The other parameter compared was cost benefit liter per year using cleaner recycling leading to environmental advantage. There are nine technologies used in this industry that has been analyzed.

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M. Prashanthi et al. (eds.), *Bioremediation and Green Technologies*, Environmental Science and Engineering, https://doi.org/10.1007/978-3-030-64122-1_14

Keywords Conventional technology · Cleaner technology · Return on investment · Recycling

1 Introduction

Sugar is one of the largest agro-based industries. Sugarcane, a major raw material, is an important crop for bio-products because it produces sugar with a by-product bagasse (Renouf et al. 2008). Bagasse is used as involvement resource in 80 sugarcane producing countries (Botha and Von Blottnitz 2006). In the world over, the top of five nations viz., India, Brazil, Thailand, Australia, and China, accounted for 40% of the total sugar production, while sugar is produced in about 115 countries in the world. Sugar is produced 70% from sugarcane and 30% from sugar beet and cassava, etc. (Contreras et al. 2009). In the year of 2015–2016, 526 mills are operated in India, which produced 33.90 million tons of sugar from Andhra, Pradesh, Karnataka, Madhya Pradesh, Tamil Nadu and Uttar Pradesh (ISMA 2012). Sugar industry is mainly seasonal and operates only for 150–210 days in a year (November–May) (Kolhe et al. 2009). A huge volume of waste is generated during the operation of sugar production and has a huge amount of pollution load; classified in terms of suspended solids, organic matter, and press mud, bagasse and air pollutants another important is wastewater. The mills generate wastewater in the ratio of 1:2 (Jadhav et al. 2013; Vinish 2014). Each process in the sugar industry with crushing capacity of 1500–5000 tons per day requires 1500–10,000 m^3/day of water. Sugar industries are used for chemical and coagulation of impurities and refining of end products. These entire chemicals, one-way or another, are contributing towards increased water pollution level. Sugar mills account in the industries which discharge huge amount of effluent per day without any or partly treatment during the crushing season (Trivedy 1998). Sugar industry is categorized under the highly polluting water industries (Red category industry) (CERP 1989). To drop this the mandatory laws of pollution control board stipulated to the sugar industry to install ETP with CPCB prepared in accordance to the guidelines dated in 19-01-2015, On techno-Economic feasibility for implementation of Zero liquid discharged (ZLD) mechanism for reuse and recycle the effluent water conservation and irrigation protocol as alternate to ZLD water(CPCB 2015). To install continuous effluent online monitoring system (CEMS) for all the ETP for the measurement of parameters like flow pH, COD, BOD and TSS (CPCB 2015) corresponding by the flow meter.

2 Study Area

The study of select sugar industry is situated in Erode is an “Ultra red” category industry as the pollution load is very high. The production of sugar is 4750 TCD (tonne capacity per day).

2.1 Materials and Methods

Economic Parameters

Cost variables: In this cost analysis basic cost parameters like capital investment, variable cost, Buy back cost and viability of the mechanism (Life time of the mechanism in years) of the two treatment process are Elicited by the environmental engineer has a secondary data this are necessary cost to find (Benefit cost per liter).

VC = Variable cost, FC = Fixed cost, BB = BuyBack cost, Viability Period of the mechanism.

3 Steps Involved

1. **The total Buyback cost** is equal to capital investment in Rupees. Multiply with buyback cost in percent, is divide by 100 is equal to Rupees. (Total buyback cost).
2. **Actual capital Investment** equals to capital Investment in Rupees minus Total buyback cost in Rupees is equal to fixed cost per year in Rupees,
3. **The Fixed cost** is given fixed cost equals Actual capital investment in rupees divided by viability period of the mechanism in years, it's given Rupees,
4. **Total cost (TC)** equal to fixed cost in Rupees per year plus variable cost in Rupees, gives Rupees minus Depreciation cost per year.
5. **For Return on Investment (ROI)** Profit is equal to benefited amount—Total cost + Depreciation cost per year.

4 Cost Variables for Return on Investment (ROI)

In this cost analysis basic cost parameters like capital Investment, variable cost, Buy back cost and viability of the mechanism (Life time of the mechanism in years) of the two technology are Elicited from the environmental engineer and energy auditor has a secondary data this are necessary for cost variables to find Return on investment (ROI) (Phillips and Philips 2006).

$$\begin{aligned} &\textbf{Profit} = \textbf{Total Revenue} - \textbf{Total operational cost}. \\ &\textbf{Return on Investment (R.O.I)} = \textbf{Profit/Total cost} * \textbf{100} \end{aligned} \tag{1}$$

Cost variable for Cost Benefit Ratio is (Total Revenue) and Total cost (Fixed cost + Variable cost + Depreciation cost + Pollution and operational cost (Siva 2016).

Note: Cost benefit Ratio is equal to Total Benefit value divided by Total cost.

$$\textbf{Cost benefit Ratio} = \textbf{Total Benefited Value or Total Revenue/Total Cost} \tag{2}$$

Figure 1. shows the operational flowchart of select sugar industrial unit production process, this flow chart describes a classification of pollution control technologies in water (closed-loop), air, solid waste (co-processing) and energy conserve (co-generation and inbuilt technology), this industry has adopted conventional (older), cleaner (newer) technologies which is described detail below in Tables 1 and 2 with a detail explanation of concepts.

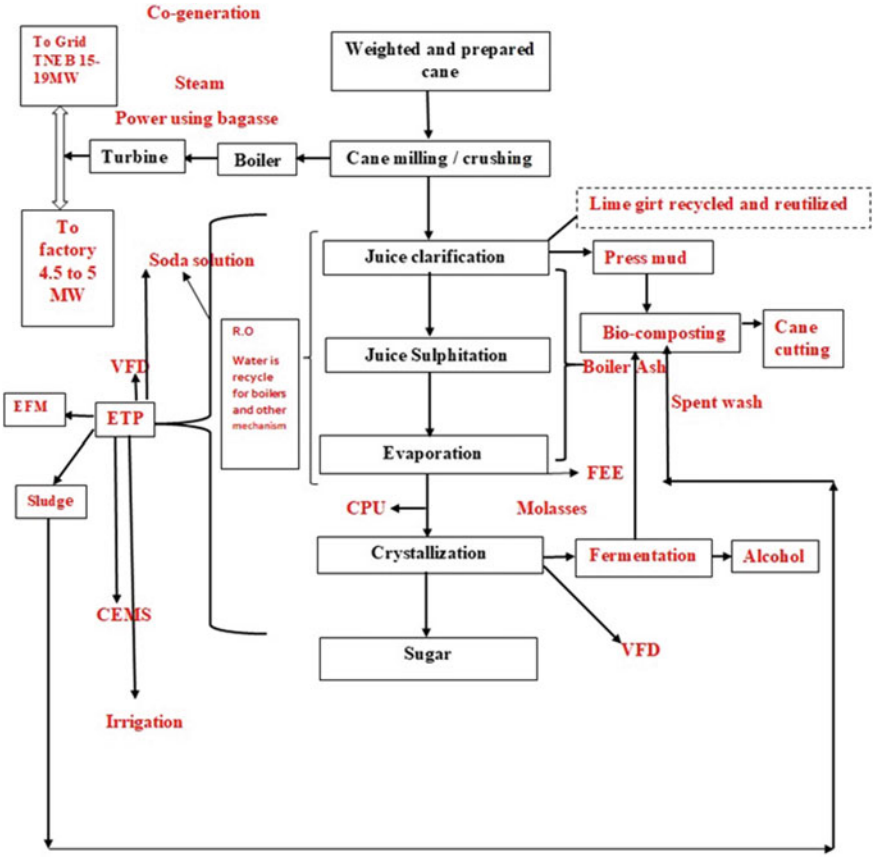

Fig. 1 The operational process and cleaner technology used in select sugar industry

Table 1 Comparison between cleaner and conventional technology using return on investment and cost benefit ratio (ROI and CBR) in select Sugar Industry

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
1.	**Condensate polishing unit (CPU*)**	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs.500 lakh Rs.7.33 lakh p.a. 10 years 6% Rs.0.35 lakh p.a. **Rs.33.75 lakh p.a** **22,500,000 liter p.a** Rs. 54.33 lakh p.a.	Rs.700 lakh Rs.10.55 lakh p.a. 20 years 7.5% Rs.0.695 lakh p.a. **Rs.81 lakh p.a** **54,000,000 liter p.a.** Rs. 42.92 lakh p.a.	−38.5	**87.1**	**0.6121**	1.887

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
2.	**Cooling tower technology**	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** **8. TC**	Rs. 20 lakh Rs. 1.7 lakh p.a. 8 years 5% Rs. 0.25 lakh p.a **Rs. 108 lakh p.a.** **72,000,000 liter p.a.** Rs. 4.075 lakh p.a.	Rs. 34 lakh Rs. 7.06 lakh p.a. 20 years 6.5% Rs. 0.5 lakh p.a. **Rs. 202.5 lakh p.a.** **135,000,000 liter p.a** Rs. 8.64 lakh p.a.	1881.5	**2237.9**	**26.50**	23.43

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
3.	**Effluent treatment plant with (ASP*) and RO* UF*and MGF*.**	**1**. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost 6. **Profit** **7. Benefit** 8. TC	Rs. 435 lakh Rs. 24.77 lakh p.a. 25 years 12.5% Rs. 1 lakh p.a. **Rs. 283.5 lakh p.a.** **189,000,000 liter p.a** Rs. 40.99 lakh p.a.	Rs. 1250 lakh Rs. 97.3 lakh p.a. 10 years 14% Rs. 8.54 lakh p.a. **Rs. 208.88 lakh p.a.** **52,200,000 liter p.a.** Rs. 204.8 lakh p.a.	**605.8**	−2.17	**6.916**	1.019

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
4.	**Co-generation**	**1.** Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost 6. **Profit** **7. Benefit** 8. TC	Rs. 550 lakh Rs. 9 lakh p.a. 4 years 6.5% Rs. 2.35 lakh p.a. **Rs. 9.24 lakh p.a.** **N.A** Rs. 137.56 lakh p.a.	Rs. 9500 lakh Rs. 156 lakh p.a. 20 years 6.5% Rs. 10 lakh p.a. **Rs. 162.45 lakh p.a.** **3,420,000 p.a.** Rs.5 97.4 lakh p.a.	−94.99	**−73.8**	0.0671	**0.2719**

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
5.	**Variable frequency drive (VFD)**	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost **5.** Depreciation **cost** **6. Profit** **7. Benefit** 8. TC	Rs. 20 lakh Rs. 0.1 lakh p.a. 5 years 5% 0.1 **Rs. 0.1025 lakh p.a.** **7000 (kWh) p.a.** Rs.3.9 lakh p.a.	Rs. 45 lakh Rs. 0.5 lakh p.a. 10 years 7.5% Rs. 0.33 lakh p.a. **Rs. 2.58115 lakh p.a.** **54,340 (kWh) p.a.** Rs.4.66 lakh p.a.	−99.93	**−51.7**	0.026	**0.5538**

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
6.	**Free flowing evaporator (FFE)**	**1.** Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs. 450 lakh Rs. 40 lakh p.a 10 years 5% Rs. 0.5 lakh p.a **Rs. 3.0875 lakh p.a.** **60,720 (kWh) p.a.** Rs. 80.75 lakh p.a.	NA*	−96.79	NA*	0.03823	NA*

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
7.	**Air pollution control (Double stage Electrostatic precipitator)**	**1.** Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs. 150 lakh Rs. 14.55 lakh p.a. 10 years 8% Rs. 10.6 lakh p.a. **Rs. 0.52 lakh p.a.** **11,000 (kWh) p.a.** Rs. 28.3 lakh p.a.	NA*	−135.6	NA*	0.01837	NA*
8.	**Caustic Soda processing**	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs. 35 lakh Rs. 0.3 lakh p.a. 4 years 5% Rs. 0.1 lakh p.a. **Rs. 3.087 lakh p.a.** **638,720 (kWh) p.a.** Rs. 8.6125 lakh p.a.	NA*	NA*	−65.31	0.358	NA*

(continued)

Table 1 (continued)

S. No.	Technology	Cost variables	Conventional technology parameters	Cleaner technology parameters	Return on investment (ROI)		Cost-Benefit Ratio (CBR)	
					Conventional Technology (%)	Cleaner technology (%)	Conventional technology	Cleaner technology
9.	**Cane Cutting processing**	**1**. Capital Investment 2. Variable Cost 3. Viability period 4. Buyback cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	NA*	Rs. 22 lakh Rs. 7.55 lakh p.a. 30 years 10% Rs. 25 lakh p.a. **Rs. 5.1 lakh p.a.** **1,700,000 cane cutting p.a.** Rs. 14.81 lakh p.a.	NA*	**58.7**	NA*	**0.3443**

*ASP** Activated sludge processing, *RO** Reverse Osmosis, *MGF** Multi-grade Filter, *NA* Not Available, *TC* Total cost, *p.a.* per annum, kWh- kilowatt-hour

Table 2 Comparison between cleaner and conventional technology using cost benefit per liter and liter benefit per year in select Sugar Industry

Technology	Cost variables	Conventional technology cost parameters	Cleaner technology cost parameters	Cost benefit liters		Total Liters benefit per year	
				Conventional technology	Cleaner technology	Conventional technology	Cleaner technology
Condensate polishing unit (CPU)	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs.500 lakh Rs.7.33 lakh p.a. 10 years 6% Rs.0.35 lakh p.a. **Rs.33.75 lakh p.a.** **22,500,000 liter p.a** Rs.54.33 lakh p.a.	Rs.700 lakh Rs.10.55 lakh p.a. 20 years 7.5% Rs.0.695 lakh p.a. **Rs.81 lakh p.a.** **54,000,000 liter p.a.** Rs.42.92 lakh p.a.	**0.2414**	0.07948	4.141	**12.58**
Cooling tower technology	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs.20 lakh Rs.1.7 lakh p.a. 8 years 5% Rs.0.25 lakh p.a **Rs.108 lakh p.a.** **72,000,000 liter p.a.** Rs.4.075 lakh p.a.	Rs.34 lakh Rs.7.06 lakh p.a. 20 years 6.5% Rs.0.5 lakh p.a. **Rs.202.5 lakh p.a.** **135,000,000 liter p.a** Rs.8.64 lakh p.a.	0.0056	**0.0064**	**176.6**	156.25
Effluent treatment plant with (ASP*) and RO* UF*and MGF*.	1. Capital Investment 2. Variable Cost 3. Viability period 4. BuyBack cost 5. Depreciation cost **6. Profit** **7. Benefit** 8. TC	Rs.435 lakh Rs.24.77 lakh p.a. 25 years 12.5% Rs.1 lakh p.a. **Rs.283.5 lakh p.a.** **189,000,000 liter p.a** Rs.40.99 lakh p.a.	Rs.1250 lakh Rs.97.3 lakh p.a. 10 years 14% Rs.8.54 lakh p.a. **Rs.208.88 lakh p.a.** **52,000,000 liter p.a.** Rs.204.8 lakh p.a.	0.0216	**0.392**	**47.132**	2.54

*ASP** Activated sludge processing, *RO** Reverse Osmosis, *MGF** Multi-grade Filter, *NA* Not Available, *TC* Total cost, *p.a.* per annum, kWh- kilowatt-hour

5 Explanation of Cost Analysis Using ROI, CBR, cost-benefit per year and benefit liter per year for CPU

Water requirement is enormous in the case of sugar industry production; the mode of water supply for this sugar industry to a large extent is from ground water. Condensate polishing unit (CPU) the return on investment in conventional technology is (−38.5%) and cleaner technology is (87.1%) for Rs. 1 investment. On comparing the two technologies Cleaner technology (upgraded CPU) shows a higher ROI. In terms of cost-benefit ratio conventional technology (0.6212) and cleaner technology (1.887) and so cleaner technology shows a higher benefit. The Environmental advantages of recycling water using CPU is 54,000,000 liter per year. Cost-benefit per liter in conventional technology is (0.2414) and cleaner technology is (0.0794). Benefit liter per year in conventional technology is (4.141) and cleaner technology is (12.58). The benefit liter per year in cleaner technology is higher than the conventional technology. The cost benefit per year is higher in conventional than cleaner technology due to the quantity of water is higher (recycle of hot water 3 times a day), the annual cost saving from CPU is Rs. 81 in lakh. per year, as shown in (Tables 1 and 2).

6 Explanation of Cost Analysis Using ROI, CBR, cost-benefit per liter and benefit liter per year for Cooling Tower

Cooling tower the return on investment in conventional technology (1881.5 percent) and (2237.9 percent) for Rs. 1 investment. On comparing the two technologies Cleaner technologies (upgraded cooling tower) shows a higher ROI and In terms of cost-benefit ratio conventional technology (26.50) and cleaner technology (23.43) in term of cost-benefit ratio conventional technology shows a higher benefit. The Environmental advantages are recycling of water using in cooling tower is 135,000,000 liters per year, Cost-benefit per liter in conventional technology is (0.0056) and cleaner technology is (0.0064) the cleaner technology shows slightly higher in value. Benefit liter per year in conventional technology is (176.6) and cleaner technology is (156.25) conventional technology shows a higher liter of benefits per year than cleaner technology. The annual cost saving from water saving is Rs. 202.5 per year in lakh. Though cleaner technology showed lesser cost-benefit ratio than conventional technology, the environmental advantage offsets this through water saving, as shown in (Tables 1 and 2).

7 Cost Analysis Using ROI, CBR, cost-benefit per liter and liter benefit per year using for ETP and Advance Treatment Technology (MGF, RO, UF)

As shown in (Tables 1 and 2), Effluent treatment plant (ETP) the return on investment in conventional technology (Activated sludge process) is (605.8%) and cleaner technology (MGF (Multi grade filter), RO (Reverse osmosis) and UF (Ultra filtration) is (−2.17%) for Rs.1 investment. Comparing the two technologies, conventional technology is gain and cleaner technology is loss and the operational and maintenance cost is very high comparing with the conventional technology cost. In terms of cost-benefit ratio conventional technology (6.916) and cleaner technology (1.019), leading to conventional technology showing a higher benefit. Cost-benefit per liter in conventional technology is (0.0216) and cleaner technology is (0.393) and liters benefit per year in conventional technology is (46.10) and cleaner technology is (2.53). Conventional technology shows a higher value in the cost-benefit per liter. The amount of water used is very less in cleaner technology due to the recycled water being used only for boiler feed purpose with of 52,000,000 liter per year and ETP the advantage are 70 Tons per year (70,000) and the water recycle is 1890 lakh liters per year and the benefited amount is Rs. 208.88 per annum in lakhs and thus the total benefit from the Effluent treatment plant (ETP) is Rs. 283.5 per annum in lakhs. CPU, Cooling tower, ETP (ASP) and MGF, RO, UF is said to be a "closed-loop system" water is recycled has an "add-on" technology and the end of recycling process from the ETP and aeration tank the water is send to irrigate 94.77 acres of sugar cane farming land.

8 Conventional Technology

ASP used in ETP as a secondary treatment technology in sugar industry has outcome advantage in sludge processing and can be reused as a composting material, but on comparing with the TNSPCB standards, after treatment the outcome exceeds the permissible limits in parameters like BOD, COD, TDS, Sulphate, Chloride, Sodium and oil grease high organic load, has been there since the inception of the industry in 1980s and has led to advance technology Viability of this ASP used as an "add-on" technology in this industry to screen the primary water pollutants is evident and this whole system CPU, Cooling tower, ETP with advance technology is called has "Closed-loop" water system technology without wasting of water or draining the water into surface water, as shown in (Tables 1 and 2).

9 Explanation of Cost Analysis Using ROI and CBR for Co-generation

Regarding Co-generation, from 1986 to 1990 industry used direct electricity from non-renewable energy source this is the conventional technology (−94.99%) and from 1990 "Igni fluid" boiler form bagasse (Co-generation) was installed as cleaner technology (-73.82%) for Rs. 1 investment. Comparing the two technologies cleaner technology (Co-generation) shows a higher ROI, but there is loss. In terms of cost-benefit ratio, conventional technology (0.0671) and cleaner technology (0.2719), (shown in Table 2) cleaner technology shows a higher benefit.

9.1 Advantage of Co-generation

1. It is as follows: power export to grid during season, Sugar plant and aux consumption: 4.5–5 MW, Power export to TNEB Grid 8–10 MW 77.28 GWh; emission reduction, 62950.75 tonnes per year; and annual revenue at Rs. 270/tonne of CO_2 reduction, Rs. 1.7 crores.
2. About 15% of coal is used for initial ignition of the raw material, 85% biomass, has raw materials with a ratio by calculating the specific calorific value (CV) with quantity approximate usage determine per annum. For steam production-825, Enthalpy, 2081 Cv.
3. Running Period, 180–250 days; power export to grid, 10–14 MW; power cost given by Tamil Nadu electricity board (TNEB) using bagasse as a fuel, Rs. 4.52/unit; power cost given by TNEB using bagasse and coal as a fuel, Rs. 4.50–4.90/unit; total sales during off season, Benefits in Rs. 16,245,000 per year.
4. 85 percent biomass has raw materials, only 15 percent of coal is used as per government norms.
5. Power savings is 3,420,000 kWh per year.
6. Air pollution is very low as compared to other technology like nuclear power and atomic power as the dispersion of the air is too low in the stack. Double stage Electrostatic precipitator (ESP) is used to control the air pollution.
7. The farmer gets Economic benefit due to selling their raw material (biomass) for co-gen like Coconut shell, Julie flora, Pith, Chipper dust, Groundnut shell to the industry.
8. Solid waste generated by Boiler Ash-Bagasse 21.67(T/D), Boiler Ash coal 30 (T/D) Bagasse ash will used as manure and coal ash will be sold out to brick manufactures.

Advantage: Automated flow meter for energy calculation. No human error accurate in readings, Energy saving technology, Automated sensor are attached.

10 Energy Conservation Technology

10.1 Process Description of Variable Frequency Drive (VFD)

Principle is Changing Direct current into Alternate current. Key areas were (Variable frequency drive) VFD used. Effluent treatment plant (ETP), Molasses tank, Membrane technology, cooling tower blowdown, washing and process condensate polishing unit (CPU), Boiler water feeding and falling-film evaporators (FFE). Conveyor belt and some of the other auxiliary instruments (Figure 1, shown in Table 1).

Explanation of Cost Analysis using ROI and CBR for VFD

In Variable Frequency Drive (VFD), conventional technology is (−99.93%) and energy conversation technology, 2004, where auxiliary equipment was introduced in this industry by process modification "energy saving" Variable frequency drive (VFD) is the cleaner technology showing (−51.7%) for Rs. 1 investment. Both values are negative, depicting loss in conventional and cleaner technology but cleaner better. In terms of cost-benefit ratio conventional technology (0.026) and cleaner technology (0.5538), cleaner technology shows a higher value of benefit than conventional technology. But the energy saving 54,340 kWh per year and benefit amount is Rs. 2.58115 lakh per year as shown in Table 1.

10.2 Falling Film Evaporator (FFE)

Explanation of Cost Analysis using ROI and CBR for FEE

Free Flowing evaporator (FFE) is conventional technology (−96.79%) for Rs.1 investment it's a loss. In terms of cost-benefit ratio conventional technology (0.0382) the benefits is less in terms of cost benefit. But the Energy saving 60,720 kWh per year and benefit amount is Rs. 3.0875 lakh per year. Attaching online sensor's and automated variable frequency drive, automated flow meters, as shown in Table 1.

Benefits: This is used for internal cleaning purpose of the boiler and energy conserving technology.

10.3 Air Pollution Control (Double Stage Electrostatic Precipitator)

Explanation of Cost Analysis Using ROI and CBR for Air Pollution Control (Double Stage Electrostatic Precipitator)

Air pollution control (Double stage Electrostatic precipitator) is conventional technology with (−135.6 percent) for Rs.1 investment in terms of ROI is a benefit. The cost-benefit ratio shows (0.01837) implying there is loss (shown in Table 1). But the Energy saving 11,000 kWh per annum, Rs. 0.52 lakh per annum.

10.4 Caustic Soda Processing

Explanation of Cost Analysis using ROI and CBR for Caustic soda

Caustic soda processing is a conventional technology ROI for Rs.1 investment is (−65.31 percent) which is a loss and the cost-benefit ratio of conventional technology is 0.358 the benefits is less in terms of cost-benefit analysis . But the energy saving 638,720 kWh per annum, Rs. 3.087 lakh per annum.

Advantage: Works on recycling process to neutralize the pH of spray pond and cleaning substance used in the Falling flow evaporator, Attaching on-line sensors and automated variable frequency drive, automated flow meters.

Benefits-This is used for internal cleaning purpose of the boiler and energy conserving technology.

10.5 Cane Cutting Technology

Selecting Seeds

Peeling sugarcane leaves: peeling leaf sheaths of sugarcane seeds first before the seeds are chopped after the seeds are selected, chopping off tails of lower parts from growing points for 4 to 5 cm and old stems away from the ground for 80 to 100 cm, and using most middle sugarcane stems as the sugarcane seeds, Raising nursery using single-budded chips (conventionally, 2–3 budded sets are used and normally no nursery is prepared) (Shaochun et al. 2015).

Explanation of Cost Analysis using ROI and CBR for Cane Cutting

Cane cutting processing conventional technology (58.7 percent) for Rs. 1 investment it's a gain. In terms of cost benefit ratio conventional technology value is (0.344), the benefits are high (shown in Table 1). Because this is directly utilized by the farmers in their farmland due to the yield is high. Cane cutting saving of Rs. 17 lakh per year

and also a benefit amount is Rs. 5.1 lakh per year through bio-remediation shows the positive environmental benefit.

Benefits of Cane Cutting

A new and simple method of waste cane collection was implemented in an effective way to save the manpower and to create space of 150sq ft for other usage and by using this seeding framer will get a high yield in can production. Savings Rs. 0.06 lakh per month, Press mud are used as composting material (biomass fertilizer).

11 Recycle Products in Sugar Industry

Raw material consumption

Shows the Consumption of Raw Material Per Unit of Output

Sugar = cane crushing quantity/sugar cane quantity = 713,904.693/70950.30 = 10.062
Bagasse = cane crushing quantity/bagasse quantity = 713904.693/191607.029 = 3.726
Filter mud = cane crushing quantity/filter mud quantity = 713904.693/27811.630 = 25.669
Molasses = cane crushing quantity/molasses quantity = 713904.693/32630.23 = 21.879
Bio-compost = cane crushing quantity/bio-compost quantity = 713904.693/181.06 = 3942.9

Shows the Product and By-Product Produced on % Cane

Sugar recovered = sugar quantity/cane crushing quantity* 100 = 70950.30/713904.693 * 100 = 9.96
Bagasse = Bagasse quantity/cane crushing quantity * 100 = 191607.029/713904.693 * 100 = 26.84
Filter cake = Filter cake quantity/cane crushing quantity * 100 = 2780.620/713904.693 * 100 = 03.90
Molasses = Molasses quantity/cane crushing quantity * 100 = 32620.23/713904.693 * 100 = 4.57

By Products

Bagasse, Molasses, Press-mud, Boiler ash, Coal ash, Lime grit are three important by-products of Sugar Mill.

Bagasse

Bagasse, the residue after the extraction of juice from the cane, is rich in cellulose fiber, which is a major source of energy, and it is being the major substitute raw

material for wood and bamboo used in the paper and pulp industry, Bagasse produced was depithed and sold as raw material for paper manufacturing only about 75% of the quantity. The remaining 25% is called the pith, is used in boiler as fuel. Bagasse is used has a raw material for energy production in Co-generation plant for Sugar industry about 119,970 tons are produced per year and the Benefit in Rs. 850 lakh per year.

Sludge from ETP: Press mud is added with ETP sludge to make bio-compost about 42 tons per year, Sludge thickener, used in Bio-compost the benefited amount is Rs.31 lakh per year.

Molasses

Molasses, a residue, subsequent to extraction of sugar from juice, is a storehouse of organic chemicals, like ethanol, ether, methanol and alcohol can be made by using molasses has a raw material. And this molasses is recycled in distillery industry to add alcohol in manufacturing of beer and other chemical products. In this Sugar Industry with a capacity of 4750 TCD operating for a period of 180 days would produce around 0.18 lakh tonnes of molasses per year; and this is recycled in cattle fodder field, Oil mills and distillery industry with a benefit amount of Rs. 446 lakh per year.

Press Mud or Filter Muds

Press Mud is used as fertilizer in fields, which helps in increase the cane production and used for Cane cutting purpose has a bio-compost. The production is 0.28728 tons per year and the benefit in Rs. 2.22 lakh per year.

Lime Grits: This is used for landfilling in cement factory and produced 0.0081 lakh tons per year and the benefit in Rs. 50 lakh per year.

Boiler Ash and Coal Ash: Boiler ash produced is 0.039006 lakh Tons per year and reused in cement manufacturing and the cost-benefit is Rs. 123 lakh per annum and coal ash produced is 0.054 lakh Tons per year and cost-benefit is Rs. 140 lakh per annum coal ash will be sold out to brick manufacture industry as it can also be used has a raw material.

Belt Conveyor: Control adsorption Cost savings Rs. 0.07 lakh per annum, Dust collector collects the dust in the Hooper, Pan Hooper Control's adsorption, Sprinklers Control adsorption, Green Belt 8522 and cost for the plantation is 5 lakhs. Coconut Plantain, Teak, Palm, Ashoka, Neem, Sobibul, Casurina and Pungan (Natural bio-remediation to control air pollution), Rain water harvesting for (recharging of rain-water).

12 Discussion

The sugar industry selected for study situated in Erode started in 1984, a large scale industry and Red category (Annexure B in EIA), has a Bagasse co-generation plant for paper board industry. The adverse effects of the industry like utilization off arm land for sugar cane production with Cauvery running at a distance of 0.5 km functions with a capacity of 2500 TCD (Tons capacity per day) which has now increased to 4750 TCD and this large scale red category industry has been running successfully around 180 to 200 days in a year. Presently this unit incorporates advance technologies like co-generation, co-processing, recycling, inbuilt, process-modification and closed loop water saving system technology, advanced effluent treatment plant (ETP) technology to have reusing capacity, energy conservation technology "closed-loop" of water saving technology to achieve zero liquid discharge (ZLD) connects, condensate polishing unit (CPU), cooling tower modification, cleaner technology. As a result, they procure a return on investment of (87.1) and CBR of 1.887. Cleaner technology has high benefit, Hot water is recycled 3 times a day, about 54,000,000 liter per year is recycled and Rs. 81 lakh per year cost-benefit per liter leading to 0.07948 and total benefit liters is 12.58 percent cleaner technology and In cooling tower ROI (2237.9%) for Rs. 1 investment and CBR the value is higher in conventional technology (26.50) Environmental benefit are higher in cleaner technology like water is recycled about 135,000,000 liters per year and profit amount is Rs. 202.5 lakh per year. But comparing the ASP, the older one was cheaper and slow on water treatment process, and the advantage are removing oil and grease is recycled as against the cleaner technology where maintenances is high. Connecting technology towards "closed-loop" system is a condensate polishing unit, cooling water in conventional technology was through the Activated sludge process (ASP). Cleaner technology used RO-Reverse osmosis, MGF-Multi grade filter, and UF-Ultra filtration as add-on technology. Return on investment in effluent treatment plant showed Conventional technology as (605.8%) and cleaner technology as (−2.17%) shows there is a gain by using older technology and in new by modifying the process through add-on. In the cost-benefit conventional technology shows advantage (6.916) than cleaner technology. There is also benefit on improvement of water by recycling and used in irrigation purpose where cost-benefit per liter in conventional technology is 0.02169 and cleaner technology is 3.92337. The energy saved by using the technology, Co-generation, return on investment show Conventional technology (Renewable energy) is (−94.9%) loss and cleaner technology is (−73.8%) for an investment Rs. 1. Compared to conventional technology, cleaner technology is slightly low due to operational and maintenances cost which is high and the capacity is huge. Comparing the cost benefit ratio value co-generation shows a higher value (0.2719) than conventional technology. Using Biomass as raw material, power savings is 3,420,000 kWh per year and Rs. 162.45 lakh per year is the profit. For cleaner technology, Variable frequency drive (VFD) is (−51.7%) for an investment Rs. 1, cleaner technology is slightly low as operational and maintenances cost was low than conventional technology. VFD was attached from 2004 and advantage

was 54340 kWh per year electricity was saved.In controlling Air pollution (Double stage Electrostatic precipitator) is used return on investment was −1.0303% for Rs. 1 investment and energy savings is 11,000 kWh per year with Rs. 0.5225 lakh per year and cost-benefit ratio value is 0.01837 still in air pollution control conventional technology is used. Caustic soda processing return on investment was (-65.31%) for Rs. 1 investment and cost-benefit ratio value is 0.358 gave a benefit of Rs. 3.0875 lakh per year. Sugar industry has been recycling Lime grits is 810 tons per year, Boiler Ash and coal ash 3900.6 Tons per year were reused in cement manufacturing and the benefit-cost is Rs. 123 lakh per annum. Coal ash was produced 5400 Tons per year and the benefit-cost is Rs. 140 lakh per annum wherein coal ash would be sold out to brick manufacture industry to be used as raw material. Belt conveyor, Control adsorption Cost savings was Rs. 0.07 lakh per annum. Dust collector collects the dust in the Hooper, Pan Hooper controls adsorption in process itself, Sprinklers Controls air adsorption. Green Belt was created where about 8522 trees were planted and cost for the plantation was Rs. 5 lakhs. The trees planted were Coconut Plantain, Teak, Palm, Ashoka, Neem, Sobibul, Casurina and Pungan which act as natural bio-remediation to control air pollution. Rain water harvesting was adopted for recharging ground water. Recycling of molasses around 18,000 tonnes sent to cattle fodder, field, Oil mills and distillery industry with a profit of Rs. 446 lakh per year. Press mud was added with ETP sludge to make bio-compost about 42 tons per year, Sludge thickener used in Bio-compost earned a profit of Rs. 31,000 per year. Cane cutting (ROI) return of investment was 2.0876% and cost-benefit ratio value is 0.3433 leading to a profit of Rs. 6000 per month.

Acknowledgements The author thanks the help rendered by Dr. M. Ravichandran, Professor (Retired) Department of Environmental Management, Bharathidasan University, Tiruchirappalli in correcting the final version of the paper.

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