International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-2, Issue-10, October 2016
ISSN: 2395-3470
www.ijseas.com

Cogeneration in Indian Sugar Industry: A Review

Suresh D. Mane[1]

[1] Principal, Girijabai Sail Institute of Technology, Karwar, Karnataka, India 581345

Abstract

Cane industry is a large employment generator right from cultivation, harvesting, transportation to sugar processing in India. India has more than 500 sugar manufacturing units which manufacture sugar from sugarcane. In the past two decades after the introduction of cogeneration, most of the sugar units have opted for it and the installed capacity is 3221 MW. Plants established in recent times are all integrated complexes. The sugar units today are integrated plants which apart from manufacturing sugar, generate power and supply to the grid and also have distillery to produce ethyl alcohol. Karnataka too has 37 sugar units with installed capacity of 993 MW with ten units in the district of Belgaum. Sugar units have been set up in cooperative sector, by private sector as well as few set up in state public sector. The general trend is that the government established units and those setup in cooperative sector are not doing well and the ones managed by private sector are doing well and flourishing. This calls for study to analyse the reasons for the difference in performance which can lead way for better understanding of the cane industry. As this sector is now generating 5000 MW of power and supplying to the grid, the sector needs to be looked into properly as the power generated is ecofriendly and renewable in nature. Study of 45 research papers on sugar industry has been undertaken along with sharing the experiences of interaction with the officials of 5 sugar units in the district of Belgaum. The study can throw light on the policy implications as sustainable development demands new strategies, solutions and policy making approaches

Keywords *Indian Sugar plants, Belgaum District, Cooperative sector plants, Private Sector, Cogeneration .*

1. Introduction

The India is an energy deficit nation, as it suffers from stagnation in domestic oil production and continued increase in oil imports over the years [1]. Hence, Demand Side Management (DSM) which includes judicious energy use and enhancement in generating capacity are vital for matching the demand and supply of energy. India is perennially an energy importing nation and is shelling out nearly 7934 million USD annually in foreign exchange to import the crude oil. Central Electricity Authority vide its Load Generation Balance Report of 2013 pegs India's annual requirement of electricity at 10,48,533 Million Units (MU). However, the supply is 9, 78,301 MU leading to a shortfall of 70,237 MU i.e. a deficit of 6.7% [2]. DSM of power can assuage the situation to some extent. Apart from DSM it's quite imperative that India takes strides in increasing its installed capacity for power generation. India has lately started an exclusive ministry for new and renewable sources to promote and improve its share of renewables in the energy basket. Hence cogeneration is a very handy option to improve India's power generating capability.

1.1 Indian Sugar Industry: Current scenario

India is one of the largest sugarcane growing nations with an estimated production of around 300 million tons in the marketing year 2009-10 [3]. Now a days sugar-distillery- cogeneration complexes, integrating the production of cane sugar and ethanol, constitute one of the key agro based industries. There are nearly 500 sugar factories in India along with around 300 molasses based alcohol distilleries [4]. Karnataka in 2014 stands 3rd in cane crushing, cane recovery and 3rd in sugar production in India.

1.1.1 Products and by products of cane industry

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-2, Issue-10, October 2016
ISSN: 2395-3470
www.ijseas.com

Sugarcane cultivation is a major employer in India as it's a cash crop and the labour inputs required for the crop are minimal.

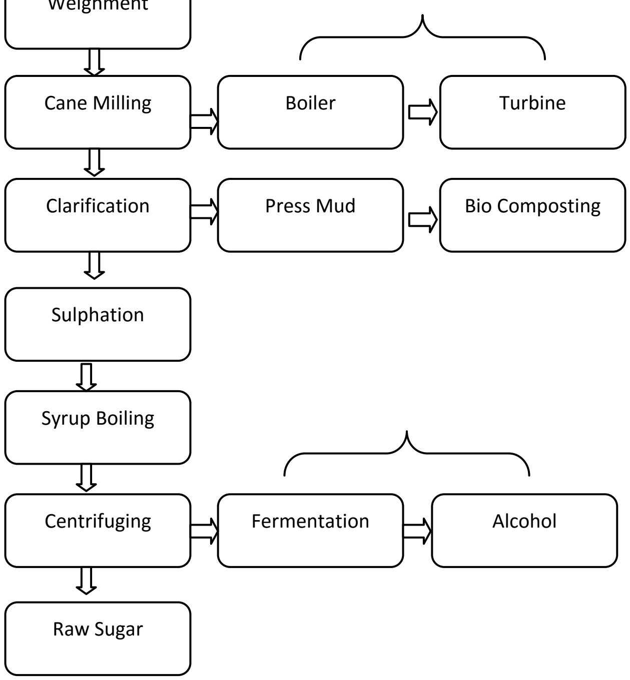


Fig.1 Sugar Manufacturing Process

India predominantly manufactures sugar from sugarcane and the manufacturing process is depicted vide Fig. 1.
The various solid waste generated include sugarcane trash; bagasse, press mud and bagasse fly ash.

Sugarcane trash: Trash refers to the leaves and tops that are obtained upon sugarcane harvesting [5]. The trash is normally disposed off by burning in the fields and the resulting ash increases the nutritional value of land.

Bagasse: It is the fibrous residue obtained after sugarcane juice extraction which contains 45 to 50 % moisture and 1 % ash [6]. Bagasse easily ignites and has free burning quality. Its calorific value is 8022 kJ/kg and is commonly used as a fuel in boilers to generate steam and electricity through cogeneration [7]. Other applications include use as a raw material in agro-residue based pulp and paper mills.

Bagasse fly ash: This is the waste generated by the combustion of bagasse. Apart from silica which is the major component, it contains other metal oxides as well as unburned carbon [8]. This waste is typically disposed off in pits; it is also applied on land for soil amendment in some areas. Approximately 0.97 million tonnes of unburned carbon is available from bagasse fly ash alone in India [9].
Press mud: This is the solid residue obtained in the sugarcane juice clarification process.

Table 1. Products and byproducts of cane industry per tonne of cane crushed

Byproduct / Product	Qty per ton of crane crushed
Sugarcane thrash	0.09-0.11 ton
Bagasse	0.25-0.3 ton
Bagasse Fly ash	0.005-0.066 ton
Press Mud	0.03 ton
Cane Juice	0.565-0.615 ton

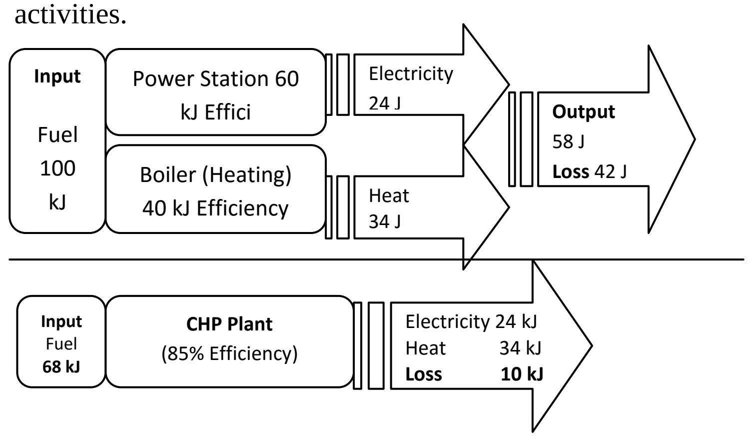
Fuels and Combustion

Combustion of bagasse in boilers for steam and electricity generation is commonly used in sugar mills. To improve energy recovery, a combination of bagasse and sugarcane trash has been investigated as a fuel in biomass integrated-gasifier/gas turbine combined cycle (GTCC) operations. This has been especially advocated in sugarcane producing countries like Cuba and Brazil [10]. Supplementing bagasse with trash is reported to enhance electricity generation by 500% [11]; however, the presence of alkali metals (Na and K) in the resulting producer gas is detrimental to the turbine blades [12]. Though extensive work has been done on this topic, no commercial BIG/GT system is reportedly operational [13]. The developments are mostly taking place in the developing countries and the technology needs to be adapted to conditions in sugar manufacturing countries.

Other factors such as feed availability (competition with other user industries), logistics of supply and cost also need to be considered. The production of fuel ethanol from bagasse is another major application. Dedini SA, Brazil has reported industrial scale production of ethanol from bagasse using an efficient pre-treatment method involving organic solvents and dilute acid hydrolysis [14]. In another initiative, a 3 ML/year bagasse based ethanol plant was commissioned in Thailand using the dilute acid steam explosion pre-treatment process [15]. However, reduction in operation costs still remains a challenge in this application; as such, extensive research on various pre-treatment methods are still underway [16]. This application has seen active industry participation as a result of high interest in renewable fuels and their anticipated market. This, in turn, has contributed towards joint research and scale-up. Sugarcane trash is normally dispersed in the fields. Thus an effective collection mechanism is required if trash is to be employed in the sugar factory for cogeneration. Alternatively, decentralized options such as conversion of trash into charcoal powder and briquette can be explored. Charcoal making kilns developed by Appropriate Rural Technology Institute of India (ARTI) have been installed in sugarcane fields and the resulting charcoal/briquettes can be used as fuel in domestic stoves [17]. Making of charcoal briquettes from sugarcane trash is being taken up in certain areas of Tamil Nadu in southern India [18]. Yet another option is trash mulching with dry leaves and also the lower green leaves. The use of sugarcane trash mulch reportedly improves soil properties, water use efficiency and nutrient uptake [19]; it also increases the yield of crops like groundnut and castor [20] and assists in weed control. In addition to fuels like ethanol, bagasse has been investigated as a starting material for the production of chemicals [21]. The cellulose/hemicellulose fractions have been modified for products like biodegradable plastics [22], adhesives etc. The bagasse has also been used as a source of cellulose whiskers [23]; such whiskers have considerable potential in reinforcing composites [24]. The lignin component has been used as a phenol substitute in phenolic molded-type resins [25], as a pesticide for insect pests and for making nanostructured films for heavy metal adsorption [26]. The driver here is the shift from petroleum based raw materials towards renewable biomass resources for chemicals production (biorefining). This is another application where industry participation in joint research with universities exists [27] and is expected to contribute towards scale up and commercialization.

2. Cogeneration

Thermal power plants are a major source of electricity supply in India. The conventional method of power generation and supply to the customer is wasteful in the sense that only about a third of the primary energy fed into the power plant is actually made available to the user in the form of electricity (Figure 3). In conventional power plant, efficiency is only one third and remaining two third of energy is lost. The major source of loss in the conversion process is the heat rejected to the surrounding water or air due to the inherent constraints of the different thermodynamic cycles employed in power generation. Losses of around 10–15% are associated with the transmission and distribution of electricity in the electrical grid. Cogeneration or Combined Heat and Power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. Mechanical energy may be used to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryer or chilled water for process cooling. Cogeneration provides a wide range of technologies for application in various domains of economic activities.



Sample CHP calculations

Fig.2 CHP calculations

The overall efficiency of energy use in cogeneration mode can be up to 85 per cent and separate heat and power has reduced to 10 units in cogeneration mode. Along with the saving of fossil fuels, cogeneration also allows to reduce the emission of greenhouse gases (particularly CO_2 emission). The production of electricity being on-site, the burden on the utility network is reduced and the transmission line losses eliminated. Cogeneration makes sense from both macro and micro perspectives. At the macro level, it allows a part of the financial burden of the national power utility to be shared by the private sector. Figure 2, represents simple calculation to show the effectiveness of CHP in a plant which requires 24 kJ of electricity and 34 kJ of heat as base load requirement. Conventionally by separate heat and power route the primary energy input in power plant will be 60 units considering an efficiency of 40 %. If a separate boiler is used for steam generation then the fuel input to boiler will be 40 units considering an efficiency of 85%. If the plant had cogeneration then the fuel input will be only 68 units considering 85% efficiency of CHP to meet both electrical and thermal energy requirements. Losses, which were 42 units in the case of, shared by the private sector; in addition, indigenous energy sources are conserved. At the micro level, the overall energy bill of the users can be reduced, particularly when there is a simultaneous need for both power and heat at the site.
Cogeneration technologies that have been widely commercialized include extraction/back pressure steam turbines, gas turbine with heat recovery boiler (with or without bottoming steam turbine) and reciprocating engines with heat recovery boiler.

2.1 Steam Turbine Cogeneration systems

The two types of steam turbines most widely used are the backpressure and the extraction- backpressure turbine. Another variation of the steam turbine topping cycle cogeneration system is the extraction-back pressure turbine that can be employed where the end-user needs thermal energy at two different temperature levels. The full-condensing steam turbines are usually incorporated at sites where heat rejected from the process is used to generate power. The specific advantage of using steam turbines in comparison with the other prime movers is the option for using a wide variety of conventional as well as alternative fuels such as coal, natural gas, fuel oil and biomass. The power generation efficiency of the demand for electricity is greater than one MW up to a few hundreds of MW. Due to the system inertia, their operation is not suitable for sites with intermittent energy demand.

2.2 Factors Influencing Cogeneration Choice

The selection and operating scheme of a cogeneration system is very much site-specific and depends on several factors, as described below:

2.2.1 Base electrical load matching

In this configuration, the cogeneration plant is sized to meet the minimum electricity demand
of the site based on the historical demand curve. The rest of the needed power is purchased from the utility grid. The thermal energy requirement of the site could be met by the cogeneration system alone or by additional boilers. If the thermal energy generated with the base electrical load exceeds the plant's demand and if the situation permits, excess thermal energy can be exported to neighboring customers.

2.2.2 Base Thermal Load Matching

Here, the cogeneration system is sized to supply the minimum thermal energy requirement of the site. Stand-by boilers or burners are operated during periods when the demand for heat is higher. The prime mover installed operates at full load at all times. If the electricity demand of the site exceeds that which can be provided by the prime mover, then the remaining amount can be purchased from the grid. Likewise, if local laws permit, the excess electricity can be sold to the power utility.

2.2.3 Electrical Load Matching

In this operating scheme, the facility is totally independent of the power utility grid. All the power requirements of the site, including the reserves needed during scheduled and unscheduled maintenance, are to be taken into account while sizing the system. This is also referred to as a "stand-alone" system. If the thermal energy demand of the site is higher than that generated by the cogeneration system, auxiliary boilers are used. On the other hand, when the thermal energy demand is low, some thermal energy is wasted. If there is a possibility,

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-2, Issue-10, October 2016
ISSN: 2395-3470
www.ijseas.com

excess thermal energy can be exported to neighbouring facilities.

2.2.4 Thermal Load Matching

The cogeneration system is designed to meet the thermal energy requirement of the site at any time. The prime movers are operated following the thermal demand. During the period when the electricity demand exceeds the generation capacity, the deficit can be compensated by power purchased from the grid. Electricity produced in excess at any time may be sold to the utility.

Cogeneration is likely to be most attractive under the following circumstances:

(a) The demand for both steam and power is balanced i.e. consistent with the range of steam: power output ratios that can be obtained from a suitable cogeneration plant.

(b) A single plant or group of plants has sufficient demand for steam and power to permit economies of scale to be achieved.

(c) Peaks and troughs in demand can be managed or, in the case of electricity, adequate backup supplies can be obtained from the utility company.

The ratio of heat to power required by a site may vary during different times of the day and seasons of the year. Importing power from the grid can make up a shortfall in electrical output from the cogeneration unit and firing standby boilers can satisfy additional heat demand.

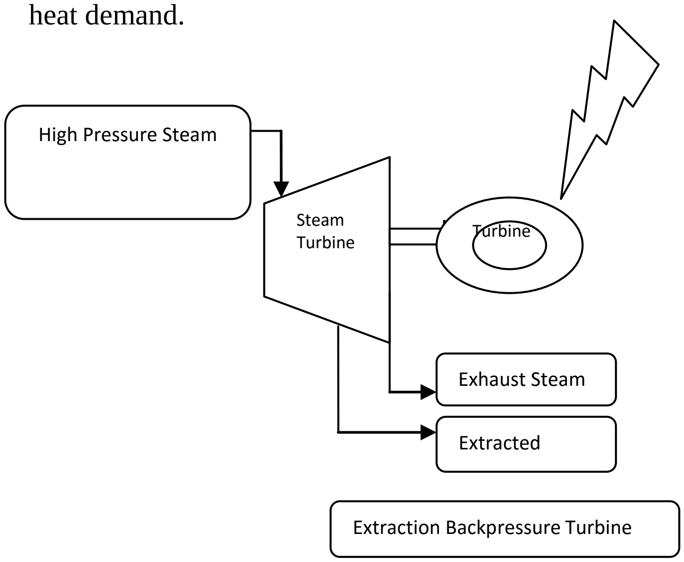


Fig. 3 Extraction and Backpressure type cogeneration system

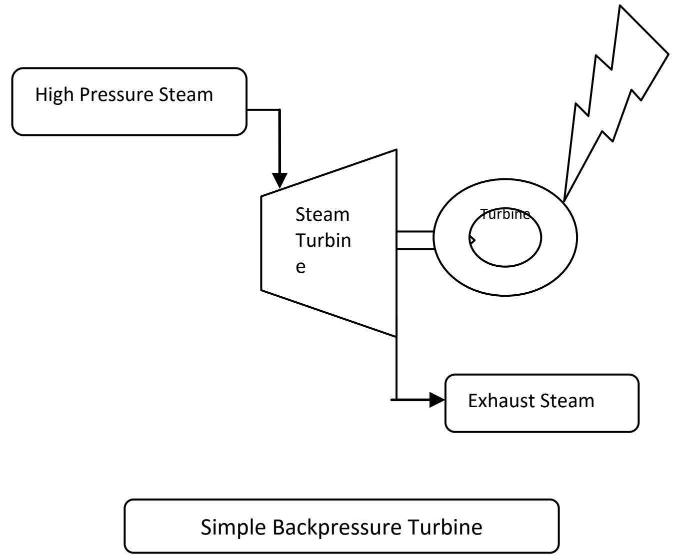


Fig. 4 Backpressure type cogeneration system

3. Environment and LCA

To meet India's projected power demand over the next 25 years, over 300,000 MWe of new generating capacity will need to be installed [28]. Cogeneration, the combined generation of steam and electricity, is an efficient and cost-effective means to save energy and reduce pollution. Many studies around the world have identified sugar mill cogeneration as an attractive low-cost power option. The United States Agency for International Development (USAID) has implemented a Greenhouse Gas Pollution Prevention (GEP) Project to assist in the direction and pace of India's power sector development. This seven-year, US$19 million effort is funded through the United States' contribution to the pilot phase of the Global Environmental Facility (GEF). The GEF's mission is to assist developing countries in investing in environmental protection initiatives that yield global benefits in terms of reduced or avoided greenhouse gas emissions. Technical aspects of the GEP Project are being managed by the United States Department of Energy's Pittsburgh Energy Technology Center. Progress in the Indian sugar industry should pave the way for cogeneration projects in other industrial sectors, such as paper, chemicals, and textiles. Contributions from these sectors are important if India is to meet its huge power generation needs

3.1 Need for Cogeneration

A major focus of the current energy debate is how to meet the future demand for electricity [29]. One of the most promising commercially available technologies is cogeneration. Cogeneration systems produce both electrical (or mechanical) energy and thermal energy from the same primary energy source.

The sugar industry in India has a potential of 3500 MW to export to the grid [30]. Energy balance carried out for an actual 5000 TCD plant alongwith pinch analysis for the sugar factory reveals that the minimum hot utility requirement is lower than the actual by 9%. Modified evaporator designs are proposed as it has been found that the existing plant is not optimum with regard to the surface area of the evaporators and the amount of steam being consumed. Exergy analysis applied to the existing and the proposed evaporator effects convey steam consumption will reduce by 9 T/h and exergy losses are reduced by 48% of its original value if the existing quadruple effect is modified to a quintuple effect.

So far, the cumulative capacity of renewable energy systems such as bagasse cogeneration in India is far below their theoretical potential despite government subsidy programmes [31]. One of the major barriers is the high investment cost of these systems. The Clean Development Mechanism (CDM) provides industrialized countries with an incentive to invest in emission reduction projects in developing countries to achieve a reduction in CO_2 emissions at lowest cost that also promotes sustainable development in the host country. Bagasse cogeneration projects could be of interest under the CDM because they directly displace greenhouse gas emissions while contributing to sustainable rural development. Annual gross potential availability of bagasse in India is more than 67 million tonnes (MT). The potential of electricity generation through bagasse cogeneration in India is estimated to be around 34 TWh i.e. about 5575 MW in terms of the plant capacity. The annual CER potential of bagasse cogeneration in India could theoretically reach 28 MT. Under more realistic assumptions about diffusion of bagasse cogeneration based on past experiences with the government-run programmes, annual CER could reach 20–26 million. The projections based on the past diffusion trend indicate that in India, even with highly favorable assumptions, the dissemination of bagasse cogeneration for power generation is not likely to reach its maximum estimated potential in another 20 years. CDM could help to achieve the maximum utilization potential more rapidly as compared to the current diffusion trend if supportive policies are introduced.

Cane sugar production by-products can be considered either as waste, affecting the environment, or as a resource when an appropriate valorization technology is implemented [32]. Study was undertaken with the objective of identifying and quantifying the aspects which have the largest environmental impact of four alternatives for using by-products and wastes from the cane sugar process and suggest improvements in the systems. The assessment is done by means of Life Cycle Assessment, according to the ISO 14040 series by using the SimaPro 6.0 LCA software, Ecoinvent database and the Eco-indicator 99 methodology.

Life cycle assessment (LCA) is a very important tool for the analysis of a process/system from its cradle to grave [36]. This technique is very useful in the estimation of energy usage and environmental load by a product/system. The demand of sugar is very high in the world market. So sugar industry is the leading industry, which produces sugar with the help of sugarcane mostly. In sugar industry, different sizes of sugar crystals and also some by-products such as bagasse, molasses, filter cake and ash are produced. Out of these, some are used an input resource in other plants like power plant and distillery for optimal utilization of waste produced in sugar industry. The outputs of power plant (electricity and steam) used in mills, distilleries, residences of sugar industry and supply to grid for sell. The molasses is the waste of sugar which is used for the production of ethanol, so molasses is a by-product of sugar industry. LCA and waste management methods are very helpful to analyse and reduce the environmental effects.

Exergy analysis successfully assesses the true thermodynamic efficiency of chemical processes [33]. It also indicates the plant irreversibility distribution among plant components, revealing those which contribute most to plant inefficiency. If the optimal values determined for the operating system parameters in this work were chosen, the total exergy loss of the plant would decrease 4.21%.

One important rationale for bio-energy systems is their potential to save fossil energy [34]. Converting a conventional sugar mill into a bio-energy process plant would contribute to fossil energy savings via the extraction of renewable electricity and ethanol substituting for fossil electricity and gasoline, respectively. Whether the saving benefits could be fully realized, however, depends on how well the potential land use change resulting from an expansion of ethanol production is managed. The results presented serve as a useful guidance to formulate strategies that enable optimum utilization of biomass as an energy source.

One of the major justifications for bio-energy systems is their low greenhouse gas (GHG) emissions compared to fossil-energy ones [35]. Transforming a sugar mill into a bio-energy plant would contribute to climate change mitigation via the extraction of renewable electricity and ethanol. Improving efficiency in electricity generation from sugar cane residues e.g. excess bagasse and cane trash is such a beneficial option. Furthermore, extracting ethanol in a so-called bio-refinery, where the coproduct stillage is utilized for energy, tends to magnify the potential benefit. The largest savings potential achieved with extracting ethanol from surplus sugar versus current practice in the sugar industry in Thailand amounts to 14 million tonnes CO_2e a year. This cannot be realized in practice until the carbon debt from land conversion is repaid, which takes 4.5–7 years, assuming that the land converted is grassland.

Performance assessment of various building cogeneration systems is conducted through energy and exergy efficiencies [37]. The cogeneration plants considered include steam-turbine system, gasturbine system, diesel-engine system, and geothermal system. Selected actual operating data are employed for analysis and performance assessment. The same amount of electrical and thermal product outputs is considered for all systems, except the diesel, to facilitate comparisons. Also, the effects of certain operating parameters (e.g., steam pressure, water temperature) on the energy and exergy efficiencies are investigated. The diesel-engine and geothermal systems appear to be thermodynamically more attractive, in that they have higher exergy efficiencies, than steam-turbine and gas-turbine systems. The results demonstrate that exergy analysis is a useful tool in performance assessments of cogeneration systems and permits meaningful comparisons of different cogeneration systems based on their merits. Such results can allow the efficiency of cogeneration systems to be increased and the applications of cogeneration in larger energy systems to be configured more beneficially, leading to reductions in fuel use and environmental emissions.

Potential of renewable energy, investment and CO_2 mitigation by renewable energy technologies [38] study reveals, India's per- capita emissions are around one tonne of CO_2/year. The present energy scene offers India a window of opportunity to invest in renewable energy. The annual turnover of renewable energy industry has reached $12.3billion in 2011, which is 36% higher than 2010 investment of $7.5 billion. Increasing the share of renewable energy in overall energy mix is an effective option to mitigate CO_2 emission. Presently, the share of renewable energy is around 12% in the energy mix. The present study estimated CO_2 mitigation potential of Indian renewable energy sector about 203 million tonnes with an installed capacity of 24 GW in 2012. However, enormous potential identified in renewable energy sector with favourable CO_2 mitigation the government is compromising with limited financial resources. However, policy efforts need to be strengthened to encourage a massive scale-up of renewable technologies to build sustained low carbon economy.

Exergy analysis of a heat-matched bagasse-based cogeneration plant of a typical 2500 tcd sugar factory, using backpressure and extraction condensing steam turbine is presented [39]. In the analysis, exergy methods in addition to the more conventional energy analyses are employed to evaluate overall and component efficiencies and to identify and assess the thermodynamic losses. The analysis is carried out for a wide range of steam inlet conditions selected around the sugar industry's export cogeneration plant. The results show that, at optimal steam inlet conditions of 61 bar and 475^{o} C, the backpressure steam turbine cogeneration plant perform with energy and exergy efficiency of 0.863 and 0.307 and condensing steam turbine plant perform with energy and exergy efficiency of 0.682 and 0.260, respectively. Boiler is the least efficient component and turbine is the most efficient component of the plant.

Bagasse power generation projects provide a useful framework for evaluating several key aspects of the Clean Development Mechanism of the Kyoto Protocol [40]. Analysis, which draws in part from a data set of 204 bagasse electricity generation projects at sugar mills, indicates that these projects provide Annex I country investors with a cost-effective means to achieve greenhouse gas emissions reductions. Our analysis also confirms that the marketplace for Clean Development Mechanism-derived offsets is robust and competitive. Moreover, bagasse projects appear to provide a positive example in a ‘‘new wave’’ of clean energy investment that has replaced the earlier industrial gas projects. At the same time, we also identify two aspects of the CDM that demand improvement. First, the additionality standard needs to be tightened and made more transparent and consistent. Financial additionality should be required for all projects; however, any financial additionality test applied by the Clean Development Mechanism’s Executive Board must be informed by the significant barriers faced by many projects. Second, the administrative processes for registration and verification of offsets need to be streamlined in order to prevent long registration time lags from chilling clean energy investment

Total site integration offers energy conservation opportunities across different individual processes and also to design as well as to optimize the central utility system [41]. In total site integration of the overall process, indirect integration with intermediate fluids or through a central utility system are preferred as it offers greater advantages of flexibility and process control but with reduced energy conservation opportunities. To achieve the maximum possible indirect integration between processes assisted heat transfer, i.e., heat transfer outside the region between process pinch points, plays a significant role. A new concept is proposed in this paper for total site integration by generating a site level grand composite curve (SGCC). Proposed SGCC targets the maximum possible indirect integration as it incorporates assisted heat transfer. In this paper, a methodology is proposed to estimate the cogeneration potential at the total site level, utilizing the concept of multiple utility targeting on the SGCC. The proposed methodology to estimate the cogeneration potential is simple and linear as well as utilizes the rigorous energy balance at each steam header.

Surplus bagasse in Indonesian sugar mills is potential for grid-connected electricity-generating projects under Clean Development Mechanism (CDM) scheme [42]. In addition, it is further perceived to considerably support the efforts to address prevailing crises in domestic sugar industry and power generation sector. Additionally, various barriers in technical, institutional, financial, and other aspects have been identified as the justifications to pass the additionality test.

Comparison of different cogeneration system scenarios for efficient energy production from bagasse fuel in an Indonesian sugar and ethanol factory [43] reveal various. Options for energy conservation which include the use of condensing-extraction steam turbines, variable speed electric drives for process equipment, measures to reduce low pressure steam demand for process needs, and two advanced cogeneration systems. One advanced system includes an 80 bar high pressure direct combustion steam Rankine cycle (advanced SRC), while the other uses a biomass integrated gasifier combined cycle (BIGCC); both utilize fuel dryers. Using steady-state thermodynamic models, we estimate that the net electricity generation potentials of the BIGCC and advanced SRC systems are approximately seven and five times the potential of the existing factory, respectively. The maximum net electricity generation potentials for the respective systems are 170 kWh/tc (BIGCC) and 140 kWh/tc (advanced SRC).

Sugar production is a major agro-based industry in India which is also labour intensive industry. Sugar industry generates various solidwastes viz. sugarcane trash, bagasse, press mud and bagasse fly ash [44].

This work examines the state-of-the-art in innovative value added products that can be obtained from the transformation of these wastes. Challenges in implementing these waste valorization solutions are also highlighted. It is observed that the extent of research and adoption of these solutions vary considerably. Both industry involvement as well as government encouragement is required in translating the research findings into commercial products

CONCLUSIONS

India predominantly was an agragarian nation with its major share of population dependent on agriculture. India has shown remarkable agility in incorporating the cogeneration technology for its sugar industry as majority of the old units have retrofitted CHP to improve their overall efficiency. The initial investment and the subsequent availability of alternate fuel during off season are two major issues which need to be addressed.

ACKNOWLEDGEMENT

The author would like to thank the officials of various sugar units of Belgaum district for sharing their experience.

REFERENCES

[[1] http://www.worldenergyoutlook.org/ IEA Energy Technology Perspectives 2010 – Scenarios & Strategies to 2050, ISBN 978-92-64-08597-8 (2010) (IEA (International Energy Agency, 2013 World Energy outlook)

[2].www.cea.nic.in/reports/yearly/lgbr_reports.pdf last accessed on 20.03.15 (CEA Website)

[3]. Singh, S., 2009. India Sugar Annual GAIN Report Number IN9049. http://gain.fas.usda. Gov / Recent GAIN Publications /Commodity Report_SUGAR ANNUAL_ New Delhi India_4-8-2009.pdf (accessed on 18 March 2014).

[4] Tewari, P.K., Batra, V.S., Balakrishnan, M., 2007. Water management initiatives in sugarcane molasses based distilleries in India, Resources Conservation and Recycling 52, 351-367.

[5] Singh, P., Suman, A., Tiwari, P., Arya, N., Gaur, A., Shrivastava, A.K., 2008. "Biological pretreatment of sugarcane trash for its conversion to fermentable sugars", World Journal of Microbiology and Biotechnology 24, 667-673.

[6]. Pessoa, J.A., Manchilha de, I.M., Sato, S., (1997) "Evaluation of sugar cane hemicelluloses hydrolyzate for cultivation of yeasts and filamentous fungi", Journal of Industrial Microbiology and Biotechnology 18, 360-363.

[7]. Babu, B.V., Ramakrishna, V., (1998) "Optimum utilisation of waste oil for improved thermal efficiency of bagasse" Journal of Indian Association for Environmental Management 25, 59-65.

[8]. Umamaheswaran, K., Batra, V.S., (2008), "Physico-chemical characterization of Indian biomass ashes", Fuel 87, 628-638.

[9]. Iyer, P.V.R., Rao, T.R., Grover, P.D., (2002), "Biomass Thermo-Chemical Characterization, third ed. IIT (Indian Institute of Technology), New Delhi.

[10]. Larson, E.D., Williams, R.H., Leal, M.R.L.V., (2001), "A reviewof biomass integrated-gasifier/ gas turbine combined cycle technology and its application in sugarcane industries, with an analysis for Cuba", Energy for Sustainable Development 1, 54-76.

[11].UNDP (2007) http:// www. undp. org/ gef/ documents/ writeups doc/cc/Brazilbiomass doc (accessed on 20 March 2015).

[12]. Gabra, M., Pettersson, E., Backman, R., Kjellström, B., (2001), "Evaluation of cyclone gasifier performance for gasification of sugar cane residue-Part 2: gasification of cane trash", Biomass and Bioenergy 21, 371-380.

[13]. Leal, M.R.L.V., (2009), "From 1st Generation Biofuels to an Integrated System Production Model Biofuels 2009 esustainable Development of Biofuels. 3rd MoEN, IEA Joint Forum Bangkok, Thailand, September 7-8, 2009, http://www.iea.org/ work/ 2009/ bangkok/ 33 Regis.pdf (accessed on 20 February 2015).

[14]. Biopact, (2007) http:// news. mongabay. com/ bioenergy/ 2007/05 /dedini-achieves-breakthrough-cellulosic.html (accessed on 18 March 2015).

[15]. Johnson, T., Johnson, B., Scott-Kerr, C., Kiviaho, J., 2010. Bioethanol e Status Report on Bioethanol Production from Wood and Other Lignocellulosic Feedstocks. http://www.beca.co.nz/projects/industrial/pulp_and_paper/w/media/ Publications/ Conference Papers/ Technical Biohanol.ashx (accessed on 18 March 2015).

[16]. Zheng, Y., Pan, Z., Zhang, R., (2009), "Overview of biomass pretreatment for cellulosic ethanol production", International Journal of Agricultural and Biological Engineering 2 (3), 51-68. http://www.ijabe.org.

[17]. ARTI (2007) http://www.arti-india.org/ content/ view/ 42/ 40/ (accessed on 20 February 2015).

[18]. The Hindu, 2010.http:// www. hindu.com /2010/02/22/stories /2010022255580700. htm (accessed on 27 November 2014).

[19]. Mahimairaja, S., Dooraisamy, P., Lakshmanan, A., Rajannan, G., Udayasoorian, C., Natarajan, S., (2008), "Composting Technology and Organic Waste Utilization in Agriculture. A.E. Publications, Coimbatore, India" http://agritech.tnau.ac.in/org farm/ orgfarm composting.html 3 (accessed on 24 November 2015).

[20]. TNAU, 2003.http:// www. tnau. ac.in/ tvm/ index. Html (accessed on 20 November 2010).

[21]. Pandey, A., Soccol, C.R., Nigam, P., Soccol, V.T., (2000), "Biotechnological potential of agroindustrial residues. I: sugarcane bagasse", Bioresource Technology 74, 69-80.

[22]. Shaikh, H.M., Pandare, K.V., Nair, G., Varma, A.J., (2009), "Utilization of sugarcane bagasse cellulose for producing cellulose acetates: novel use of residual hemicellulose as plasticizer", Carbohydrate Polymers 76, 23-29.

[23]. Bhattacharya, D., Germinario, L.T., Winter, W.T., (2008), "Isolation, preparation and characterization of cellulose microfibers obtained from bagasse", Carbohydrate Polymers 73, 371-377.

[24]. Satyanarayana, K.G., Arizaga, GG.C. Wypych, F., (2009), " Biodegradable composites based on lignocellulosic fibers: An overview", Progress in Polymer Science 34 (9), 982-1021.

[25]. Piccolo, R.S.J., Santos, F., Frollini, F., (1997), "Sugar cane bagasse lignin in resol-type resin: alternative application for lignin phenol-formaldehyde resins", Journal of Macromolecular Science 34, 153-164.

[26]. Pereira, A.A., Martins, G.F., Antunes, P.A., Conrrado, R., Pasquini, D., Job, A.E., Curvelo, A.A., Ferreira, M., Riul Jr., A., Constantino, C.J., (2007), "Lignin from sugar cane bagasse: extraction, fabrication of nanostructured films, and application", Langmuir 23 (12), 6652-6659.

[27]. Lane, J., 14 July 2010. Biofuels Digest Petrobras, BioeCON Partner for Chemicals, Green Plastics, Advanced Biofuels from Bagassehttp://biofuelsdigest.com/ digest/ 2010 / 07/14/petrobras-bioecon-partner-for-chemicals green plastics advanced biofuels from bagasse/ (accessed on 20 February 2015).

[28]. Scott M. Smouse, Gary E. Staats, S.N. Rao, Richard Goldman, David Hess, (1998), "Promotion of biomass cogeneration with power export in the Indian sugar industry", Fuel Processing Technology, 54 1998. 227–247

[29]. N. Thilak Raja, S. Iniyanb, Ranko Goic , (2011) "A review of renewable energy based cogeneration technologies", Renewable and Sustainable Energy Reviews 15 (2011) 3640–3648

[30]. J. Raghu Ram, Rangan Banerjee, (2003) "Energy and cogeneration targeting for a sugar factory" *Applied Thermal Engineering 23* (2003) 1567–1575

[31]. Pallav Purohita, Axel Michaelowa, (2007), "CDM potential of bagasse cogeneration in India, Energy Policy 35 (2007) 4779–4798

[32]. Ana M. Contreras a, Elena Rosa a, Maylier Pe´ rez a, Herman Van Langenhove b, Jo Dewulf, (2009) "Comparative Life Cycle Assessment of four alternatives for using by-products of cane sugar production", Journal of Cleaner Production 17 (2009) 772–779

[33]. Taner Tekin, Mahmut Bayramogˇlu, (2001) "Exergy and structural analysis of raw juice production and steam-power units of a sugar production plant", Energy 26 (2001) 287–297

[34]. Thu Lan T. Nguyen, John E. Hermansen, Masayuki Sagisaka, (2009), "Fossil energy savings potential of sugar cane bio-energy systems, Applied Energy 86 (2009) S132–S139

[35]. Thu Lan T. Nguyen, Shabbir H. Gheewala, Masayuki Sagisaka, (2010) "Greenhouse gas savings potential of sugar cane bio-energy systems", Journal of Cleaner Production 18 (2010) 412–418

[36]. Manish Kumar Chauhan, Varun, Sachin Chaudhary, Suneel Kumar, Samar, (2011) "Life cycle assessment of sugar industry: A review", Renewable and Sustainable Energy Reviews 15 (2011) 3445– 3453

[37]. Mehmet Kanoglu, Ibrahim Dincer, (2009), "Performance assessment of cogeneration plants",

Energy Conversion and Management 50 (2009) 76–81
[38]. Mahesh, K.S.Shoba Jasmin, (2013), “Role of renewable energy investment in India: An alternative to CO_2 mitigation”, Renewable and Sustainable Energy Reviews 26 (2013) 414–424
[39]. S.C. Kamate, P.B. Gangavati, (2009), “Exergy analysis of cogeneration power plants in sugar industries”, Applied Thermal Engineering 29 (2009) 1187–1194
[40]. Tyler McNish, Arne Jacobson, Dan Kammenc, Anand Gopal, Ranjit Deshmukh, (2009), “Sweet carbon: An analysis of sugar industry carbon market opportunities under the clean development mechanism”, Energy Policy 37 (2009) 5459–5468
[41]. Santanu Bandyopadhyay, James Varghese, Vikas Bansal, (2010) “Targeting for cogeneration potential through total site integration”, Applied Thermal Engineering 30 (2010) 6–14
[42]. Dewi Restuti, “Axel Michaelowa,” The economic potential of bagasse cogeneration as CDM projects in Indonesia”, Energy Policy 35 (2007) 3952–3966
[43]. Ranjit Deshmukh, Arne Jacobson, Charles Chamberlin, Dan Kammen, “Thermal gasification or direct combustion? Comparison of advanced cogeneration systems in the sugarcane industry”, Bi o m a s s and b i o e n e r gy 5 5 (2 0 1 3) 1 6 3-1 7 4
[44]. M. Balakrishnan, V.S. Batra,” Valorization of solid waste in sugar factories with possible applications in India: A review”, Journal of Environmental Management 92 (2011) 2886e2891
[45]. Bureau of Energy Efficiency: Guide book 2 : Energy efficiency in thermal utilities, pp 157-171.
[46]. Ravindra Magi General Manager: Personal Intearction during July 2014 at Sugar plant at Chikkodi
[47].V.S. Hiremath, Chief Engineer: Personal Intearction during March 2015 at Sugar plant at Chikkodi, Belagavi District, Karnataka
[48]George Polimerus, Industrial Press Inc.Energy Cogeneration Handbook,
[49].NPC report on “Assessing Cogeneration Potential in Indian Industries”.
[50].http://www.indiansugar.com/VirtualMill/ISMA-Sugar-VirtualMill.html
[51]. http://www.sugars.kar.nic.in/co-generation.asp
[52].http://www.sugars.kar.nic.in/docs/Annual%20Report.pdf

Dr. Suresh D. Mane passed BE in Mechanical Engineering from Karnatak University Dharwad in 1991. He joined S.C. Railways and served the organization till September 2012 when he took voluntary retirement after serving the railways for over two decades to join academics. He completed M.Tech in Energy Systems Engineering from BVB College of Engineering Hubli Karnataka in 2007 duly securing rank to the university. He enrolled for research in UBDT College of Engineering Davangere and was conferred with Doctorate by Kuvempu University Shankarghatta, Karnataka during the universities silver jubilee convocation in 2015. He has worked as Professor in two reputed engineering colleges and since 1 Oct 2015, is heading Girijabai Sail Institute of Technology, Karwar in Karnataka. He is on editorial board / reviewer for dozens of open access peer reviewed international journals and is Fellow Institute of Engineers (India) and life member of Indian Society for Technical Education. He has published 10 papers in international journals, one book chapter in Springer and presented papers in 17 conferences/ 10 workshops. His research interests include thermal engineering subjects, energy efficiency, energy management and engineering education. He is also a BEE certified energy manager and energy auditor (EA -8061).