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Power Consumption Comparison between Conventional and Two Roller Cane Crushing Mills

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Abstract**—**Lean manufacturing has become a global trend, with companies constantly striving to achieve more with less. However, many companies, including those in Pakistan's sugar industry, have yet to fully embrace this concept. With Pakistan facing electricity shortages, the country's 85 sugar mills collectively generate less than 500 MW of electricity. A traditional Sugar Mill, which currently runs at 6000 TCD, has been identified as a primary model for this upgrade.

By up gradation to 2-roller mills, instead of 4-roller or 6-roller mills, this energy production can be increased by up to 15%. After implementing this change, the mill can save up to 30% and 40-45% energy compared to 4-roller and 6-roller mills, respectively. This is due to the fewer components required with a 2-roller mill, particularly after the removal of the trash plate which consumes around 25% of the total crushing mill energy. By applying various data-gathering approaches, a model has been developed that can save over 13% of bagasse, enabling sugar mill owners to export energy to the National Grid and generate additional revenue

Keywords**—** Bagasse, Cogeneration, Fiber, Cane crushing mills, Renewable Energy.

I. INTRODUCTION

Several factors play an essential role in the shifting trend of generating electricity from Sugar Plants. First of all, increased burden on the national grid with the excess demand every year and environmental concerns linked with the burning of fossil fuels. In our country, the condition of shortage is becoming more severe as around 60% population of Pakistan is directly linked with national grid **[1]**. Nowadays, shortage of power supply is almost 6000 MW. In the years 1994, 1998 and 2002, new energy policies were developed from high authorities for generation of electric Power. The power policy of 2002, currently in action, stimulates and stretches the utilization of indigenous renewable resources **[2]**. There are numerous resources of power generation in Pakistan like Hydal, Solar, Coal etc. However, the question arises that why we are targeting the sugar mills for production of electricity while having available resources. In actuality, Pakistan has currently electricity from natural resources which comes to the value of (32.3%), Hydroelectric (24.7%), Furnace Oil (14.3%), Coal (12.8%), Nuclear (8.8%), Wind (4.8%), Solar (1.4%), Bagasse (0.9%). From bagasse, we are producing just 0.9% (almost 500 MW) **[3]**. But it has been assessed that we can increase this capacity to 3000MW by upgrading just some retrofits through co-generation **[4]**. It will not only offset greenhouse gas emissions but will also help to generate additional sources of clean energy in the country.

According to the report of the Economic Survey of Pakistan FY-2022, sugarcane is of great importance for sugar industries which is the 2nd largest agro-based industry after textile. It provides employment to the landless rural population and has a significant impact on the economy of the country. Production of this industry accounts for almost 3.7% of agriculture's total value added and 0.8% of Gross Domestic product (GDP).

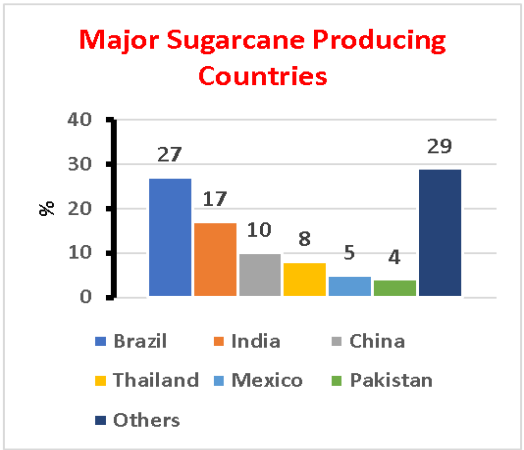

Figure 1: Major Sugarcane Producing Countries

This study is significant because Pakistan is one of the largest sugarcane producers after Brazil, India, Thailand, Mexico, and China. From these five countries' production is

almost 70% of the world's production. Sugarcane is also the second largest cash crop in the country and is being cultivated on 1.06 million hectares [5].

Now have a look at how these sugar mills operate. This Industry is the only which utilizes all its waste and is an assured eternal source of renewable energy to the world. Three main by-products of a sugar mill are bagasse (Waste of sugarcane after extracting juice), molasses, and press cake which is almost 40% of the total weight of the sugarcane crushed. Bagasse is used as a source of fuel for the sugar industry to run boilers for producing steam and juice heating. Bagasse from the milling station used as a fuel for boiler to generate steam. The steam generated from the boiler enters back pressure turbines normally installed in sugar mills to generate electricity which can be exported to the power grid as shown in the Figure 2. Coming towards the cycle in which sugar industries operate. The exhaust steam from back pressure turbine enters desuperheater to reduce and maintain the certain temperature and pressure for process house operations. The co-generation process facilities across sugar cane factories complete the energy needs of the consumer of that area successfully. It can also be helpful for commercial purposes.

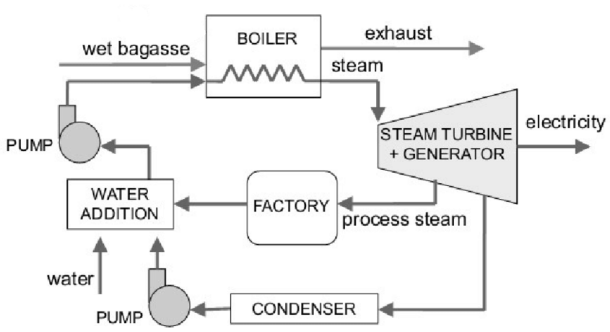

Figure 2: Working Cycle of Sugar Mills

The discussion of some existing technologies is very important like the rolling mill, low pressure boilers, condensing turbine, and evaporator. In this research paper, we will discuss how altering one of these retrofits affects or improves the efficiency of sugar mills, and increase the co-generation process, which means increasing the generation of electricity. In Pakistan, mostly sugar mills are operating with inefficient technologies and if any mill adopted the modern technology then there is no proper configuration with existing equipments of mills. Sugar mills owners are mainly focused on production of sugar instead of utilizing the energy from plant and export to national grid. Due to this reason, major amount of energy is loss in plant. There are hundreds of stations in sugar plant but most key stations are Boiler station, milling station, power house, and process house.

For crushing the sugarcane, traditionally, 6-rollers are used for crushing. Then with some advancement, 4-roller mills replaced the previous one. Nowadays, in Pakistan, very few sugar mills are using 2-rollers crushers instead of 4-rollers. We will discuss the outcomes of adopting the 2-roller mill and its effects on bagasse saving and co-generation. This is also cost-effective because the real challenge of sugar mill owners is to maintain the budget while upgrading the capacity and efficiency of plants by installing energy-efficient advanced technologies.

Many research papers have been written on this industry, but no one have highlighted the changes in some retrofits from which we can save a lot of bagasse and can produce electricity more and more. Some papers highlighted the major technological improvement due to which many revolutions came in sugar industries. In 1990 first time J. M. Ogden stated that if we use extraction condensing steam turbine in the power house of the mills, it will increase the cogeneration by almost 15% **[6].** After that many researchers suggested to introduce more efficient retrofits for cogeneration and production of electricity. In 2010, Khan Muhammad also tries to introduce his research on the sugar industry of Pakistan and introduced the production of thermoelectric power generation through the sugar industries of Pakistan **[7]**. Then in 2012, Atiq-ur-Rehman did a great effort and calculated the potential of electricity production from the sugar mills of a province of Pakistan Khyber Pakhtunkhwa **[8]**. Couples of decades back, Sugar mills were operated with roller mills having 6 rollers. The development and research work continued to improve and as a result 4 roller mill introduce and showed significant results towards the efficiency improvement of sugar plants. After passing number of years with these mills, 2-roller mills introduced as a new invention in sugar industry. It is considered to be more efficient than even 4-Roller Mills in terms of energy efficiency and economic viability.

Table-I shows the comprehensive detail of some sugarcane industry-based research papers. These are studied in details with some results and conclusions.

TABLE I
RESEARCH PAPERS BASED ON ENERGY ECONOMY IN SUGAR INDUSTRY

Ref. No (Year)	Title	Results & Conclusions
[6] (1990)	Steam economy and cogeneration in sugarcane factories.	By using some commercially available process equipment, we can reduce steam consumption in sugar industry. If we use extraction condensing steam turbines for cogeneration with high pressure boilers then there is probability to export the electricity for commercial use. It can increase the production of electricity up to 15%.

[7] (2010)	Potential thermoelectric power from bagasse by sugar mills of Pakistan.	The thermoelectric power generation by bagasse in sugar mills is discussed in detail. If we assume that this type of rolling mills run around twenty- four hours for 100 calendar days in a year, the total production of sugar waste (Bagasse) on the basis of cane crushed in 2009 was 7431 m ton per hour. The electricity produced from this scenario will be1304 MW/hr, 1,236MW/hr and 992MW/hr respectively.
[8] (2012)	The electricity generation potential in sugar mills of KPK	Electricity generation potential from bagasse in Sugar industry of a state of Pakistan is discussed. Average bagasse produced by sugar mills in that state is 786732 tons per year. Results depend upon the quantity of cane crushed and technologies utilized in mil. The results are in range
[9] (2015)	Surplus electricity production in sugarcane mills using residual bagasse and straw as a fuel.	By using Back pressure turbine and Condensing extraction turbine, almost all bagasse can be utilized as a fuel for cogeneration and produce higher amount of electricity throughout the year. System can export electricity in off-season also.
[10] (2015)	Cogeneration Through bagasse	To meet the electricity requirement for national grid, electricity production from single primary source can be applicable if required bagasse is available.
[11] (2020)	Design of a cogeneration plant for sugar Industries using Renewable energy resources	By using biomass Integrated gasification combined cycle and high pressure direct combustion steam Rankin cycle, with increase in temperature and
[12] (2004)	Energy saving cogeneration potential Mexican sugar mills	Energy saving alternatives: Using bagasse and cane residues in Mexican sugar industry by using efficient cogeneration plant which will provide all the electricity to the sugar mill and National grid also.

Based on literature studies and above refereed research papers, it is found that there is a huge potential of power saving in sugar plants. However, the target station must be a key area of sugar plant like boiler house, power house, process house and milling station. The studies has also shown that there are certain analyses of different cogeneration systems of plants, boiler house up gradation, use of extraction condensing turbines and falling film evaporator but mostly sugar plants use only existing technologies to control the steam consumption.

II. METHODOLOGY

From several years, sugar industry is playing its role in the production of electricity within the sugar mills and covering the needs of energy for factory use. During winter, when hydro power plants do not run on full capacity, power shortage becomes the challenging issue for the country to meet electricity need. Normally, sugar mills are operating to produce sugar as a major product. With the excessive bagasse available in the sugar production plant, it is being used as a fuel to generate steam which can be further processed for power generation. This concept is called “Cogeneration” which is now popular in sugar mills. So, to approach the stated problem of utilizing sugar mills in winter season, data has been taken by visiting certain sugar mills. The case study of traditional Sugar mill is prominent among them. For any model to develop, the previous history matters a lot. This is in fact adopted while doing all the technology assessments by keeping in view all the validation and verification.

In this study, the main consideration was to analyze the key areas of sugar plant where the huge energy is wasting due to conventional technologies and how efficient emerging technologies can be utilized and installed to save energy in the sugar factory

We have collected all the data according to the demographics of Pakistan. Many times during data collection, the values obtained seems unrealistic particularly when considering the other countries having a similar demographic as of Pakistan. The following four sugar mills were visited.

- Johrabad Sugar Mills Johrabad, Dist. Khushab.
- Noon Sugar Mills Bhalwal, Dist. Sargodha.
- Gulf Sugar Mills Sadqabad.
- Madina Sugar mills, Dist. Chiniot.

Design strategies are developed based on the extraction and authentication of collected results. This data was enough to build the entire model. This identifies all the required parameters for the methodology of the research work adopted. The main objective of this research is to save bagasse by installing energy efficient retrofit. Our purpose is mainly to link with the bagasse saving in adopting one retrofit within the sugar industry. Specifically, this modification is related to the use of 2-roller crushing instead of 4-roller as mentioned in the above sections. Conventional mills normally use more rollers mostly 4-rollers which increase the number of equipment attached to the mills. Consequently, the cost and steam consumption becomes high.

The existing case study sugar mill is basically low production capacity sugar mill with high steam consumption. The most critical challange in this sugar industry is to reduce the consumption of low pressure steam used in the proces house. Installation of energy efficient technologies in sugar

plants are always a challenge for plant owner as limited space availability both process house and power house side.

III. MODIFICATION OF 2 ROLLER TO 4 ROLLER

For the better retrofit technology understanding, data has been taken from PSMA and PSST. All operations and actual values have been carried out, and decisions are made upon them. The issue has been analyzed closely, and the process of mounting with its cost has been taken into confidence. Smooth feasibility plans and the estimation for steam savings have also been considered.

All the extra equipment, which is related to 4-roller (like trash plates and trash bars), does not exist in the case of 2-roller mills. So, not only does their maintenance cost goes on decreasing, but also the wear and tear are in less amount. If more surface area lies, there will be more things to handle. Fewer components come with many other benefits, including less mill adjustment, and handling operations will require less labor to take that.

Modification can save about 30% of energy through the improvement of modern equipment, i.e., 2-roller. By using this modern technology, huge quantity of bagasse can be saved during crushing season. This bagasse saving helps to fill the energy gap between the demand and production. So, this way seems a lot better for filling that gap. Visiting sugar mills and then collecting data was the most challenging task. Based on quantitative data, the model was developed to investigate the power saving potential of the plant.

The outcomes of the collected data are as follows:

- Less number of components result towards better yield as there will be more bagasse savings.
- Data for different capacities of plant in tons per day has been collected to figure out correct image of Plant's statistics.
- Plant technologies play direct role in the efficiency of the plant. If there will be more TCD, more bagasse will be produced, thus increasing the power production rate.

Data collection directly plays the role to develop the competitive model, as this totally relies on the past trends and future needs of the plant. If there are more TCD's been installed then previously, it means improved machinery can be used for better results. Improved or updated machinery will work towards the saving of steam which will be utilized in the production of electricity. The current case study comprises that the mill is running with conventional technologies like low pressure boiler, 4-roller mills, back pressure turbine and Robert type evaporator.

The replacement of above improvements and equipment can be useful for energy saving in the process house as well as key to enhance the power production for whole mill. The advanced technologies and the equipment required for the juice extraction, process house equipment and the generation of power must be carefully selected to obtain the best results in term of good balance between capital investment and operating efficiency. As a result, there has been a significant reduction in the consumption of steam and an increase in power production.

The general layout of the sugar plant needs to be considered step by step, keeping in view the retrofits. After all the work done by the farmers, sugarcane crop comes into the cane cutters, knives and shredders and finally into the cane crushers After that, it gets divided into two phases, while the juice is used for commercial purposes leaving behind the bagasse, which is utilized for fuel purposes.

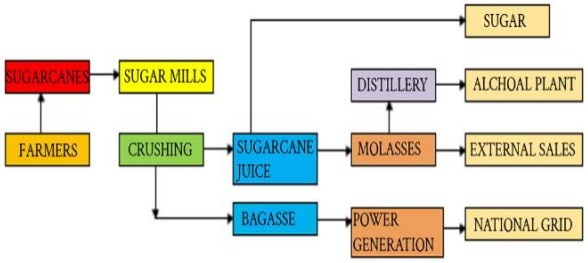

Figure 3: Sugar Plant General Layout

IV. MODEL DEVELOPMENT

A few studies have been taken out in the above sections to know more about the optimum system efficiency utilization. There is no doubt that Pakistan is one of the 6th largest sugarcane producers, but if we talk about commercial level, there is not too much which we are following the standard. The whole world is shifting from conventional technologies to modern technologies. A little has been done here, too, especially if we talk about the case study of the conventional Sugar mill.

The energy which is being produced after the consumption of bagasse needs to be utilized effectively. In this case study, the main discussion will lie on differences of applying traditional and modern technologies. The modern technology in this scenario is 2- roller crushers which has impacted the whole plant performance.

V. ASSUMPTIONS

We are exceeding our study further by keeping in view that the mill has a capacity of 6000 TCD. For the mills like this, it is better to use the word conventional because of few reasons given below:

- There is nothing like the word mechanized harvesting exists in Pakistan. As a result, we lose 1/3 of energy in fields.
- All the bagasse burned as a fuel for the cases like this because of the reasons that these kind of mills use back-pressure turbines.
- Lack of bagasse during the off-season hinders them from making excess energy.

- Most mills are not even connected to the national grid line, so they do not even think about creating their surplus unit.

TABLE II
BASIC DATA OF CASE STUDY

Attributes	Values	Units
Sugarcane crushing capacity	0.72	Million tons
Average crushing months/season	4	Months
Average sugarcane crushing/day	6000	TCD
Average sugarcane crushing/hr	250	TPH
Fiber % cane	14	%
Steam % cane	40	%
Steam to bagasse ratio	1.85	
Specific steam consumption	10	Kg/kw
Moisture % Bagasse	50	%
Pol % Cane	13.1	%
Sugarcane crushing capacity	0.72	Million tons

Conventional mills have following details.

- Size of Roller mills 42"x84"
- No of Roller 4
- No of Pinions 3
- Trash plate Yes
- Gear Box 850 KW

After the installation, the difference between the results and its savings is identifiable. However, ut before going into the results, it is much necessary to check for the assumptions first.

Currently, four-roller mill is being deployed there. So, first of all we are not just considering the amount to convert a single platform of 4-rollers to 2-rollers, instead, we are assuming that after the conversion of the whole tandem the results are given below:

VII. Results and Discussion:

In Pakistan, the deficiency of electricity has dropped up to 5944 MW. In accordance with the facts, the energy division documented that the total energy production capacity has descended to 23,556 MW against the demand of 29500 MW. So this shortfall of electric energy has created a huge demand of electric production. Hydro power plants play a key and leading rule in winters regarding the production of electricity at large scale but in winters when there's a lack of electricity generation and it's the demand rises, Sugar mills play a crucial rule. In winter when the hydro power plants lack the electricity generation sugar mills compensates that production lack since that time is the peak season of sugar mills. The peak season of sugar mills lasts for about 4 months, from February to April.

TABLE III
POWER SAVING BY USING 2 ROLLER MILLS

Attributes	4 Roller	2 Roller	Units
Cane crushing capacity	6000	6000	TCD
Average No of crushing days/season	120	120	Days
Sugarcane crushing/hr	250	250	TPH
Fiber % cane	14	14	%
Fiber generated /h	35	35	Tons/h
Power consumption/ton of fiber/mill	13	7.8	kW/ton
Power consumed by crushing mills	455	273	kW
Average No. of mills in plant	5	5	
Total power consumed for cane crushing mills	2275	1365	kW
Energy consumption/day	54600	32760	KWH
Energy consumption/ season	6552	3932	MWH
Energy saved by adopting 2 roller mill		2621	MWH

The statistical data above shows that the 4-roller mills normally consume 13 kW per ton of fiber per hour and around 455 kW power for crushing mills when assuming the crushing capacity at 6000 TCD, contrarily, 2-roller mills consume 7.8 kW per ton of fiber per hour and 273 kW power for crushing mills, making it more power efficient. The 2-roller mills save about 1/3rd of the power compared to the conventional 4-roller mill. The energy consumption for 4-roller is 54600 KWH per day and 6552 MWH per season a whole. However, energy consumption for 2-roller is 54600 KWH per day and 6552 MWH per season. Therefore, the total energy saved by 2- roller mills is 2621 MWH per season that is approximately 40% in comparison with 4-roller. The results obtained clarify that 2 roller mills is more energy efficient that conventional mills.

TABLE IV
TWO ROLLER MILL ON 15000 TCD

Attributes	VALUES		Units
Average crushing/day	6000	1500	TCD
Crushing months per season	4	4	Months
Crushing per hour	250	625	TPH
Fiber % cane	14	14	%
No of mills	5	5	
No of crushing days per season	120	120	Days
Total crushing potential in Pakistan	0.72	1.8	Million tons /season

According to the primary data of traditional sugar mills, the current capacity of mill is 0.72 Million tons per season. For a single day, an average number of sugarcane crushing approaches around 6 kilo tons. More specifically if we talk about an hour then it is 250 tons. In bagasse, moisture percentage stays around 50 % normally running mills in Pakistan.

We have also taken the experimental values of a two roller mills on 6000 & 15000 TCD. Average number of crushing months for both 6000 TCD and 15000 TCD is approximately 4. The average crushing per hour for 6000 TCD is 250 Tons per hour and for 15000 TCD, it is 625 Tons per hour. The fiber percentage of cane, for both 6000 and 15000 TCD is 14%. The average crushing potential for Pakistan, for 6000 TCD is 0.72 million tons per season and 1.8 Million tons per season for 15000 TCD. The sugar mills operate continuously in the peak season, entirely for 120 days. The results shown in table IV shows the impact of enhancing capacity of plant from 6000 to 15000 TCD. The total crushing capacity increase from 0.72 to 1.8 Million tons preseason.

A growing number of sugar plants in Pakistan are producing electricity for export to the national grid to cover the energy crisis. Power consumption in 2 roller mills is about 30% less than in 4 roller mills and 40% to 45% less as compared to 6 roller mills. It is due to less moving parts and no trash plate in 2 roller mills. (Trash plate consumes about 25% of total load).

CONCUSLION

Overall, the whole discussion can be summed up under the statement that 2-roller is efficient both in terms of energy and cost because of its lesser components. In terms of power, the 2-rollers consume much less energy than the other 3, 4, and 6-roller crushers. It is now highly recommended to install the 2 roller crushers instead of using 4 rollers. It will definitely increase the bagasse saving which in turn increase the revenue for the mill. Hence, the particulars of research are also verified by HMC Heavy Mechanical Complex, Taxila which is known to be a one of the leading supplier of complete sugar plants in Pakistan.

The primary requirement for expanding sugarcane bagasse production is an increase in crushing capacity. The mill has traditionally used 4-roller mills. However, that technique still needs to be developed enough to increase bagasse output effectively. Installing a complete tandem of the two- roller mills is the most efficient approach to improve the crashing when employing two-roller mills. Based on all the findings from the case studies, sugar plants have enormous potential to generate power during the off-season (3 months) and the crushing season.

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