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Energy Efficiency Assessment and Implementation Plans with Referance to the Case of Chashma Sugar Mills Unit-1 Dera Ismail Khan

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***Abstract*—** Energy efficiency assessment is an important tool to save energy and improve the financial gain of an Organization. Almost all the Small and Medium enterprises conducting energy audit in order to save energy and minimize energy consumption per unit product. The energy conservation is a cost effective with short payback period and modest investment

There is a bright scope of energy conservation in Pakistan in various sectors like Sugar. Textile, Cement, Fertilizer, Agriculture, Chemical process, Manufacturing, Pharmaceutical Industries. Pakistan is among the world's top-10 sugarcane producers, the potential of producing electricity from bagasse is huge. Currently there are around 83 Sugar Mills in Pakistan producing about 3.5 Million metric tons of Sugar per year with total crushing capacity 597900 TCD.which cane produce approximately 3000 MW electricity during crushing season. In Pakistan most of the industries are still using the out dated technologies; inefficient equipment's and are following inefficient operating practices. But some of the progressive industries have already using the up to dated and efficient technology and are reaping the benefits of reduced energy consumption

This paper shows the Comparison of specific energy consumption of inefficient machineries and energy efficient machineries in Chashma Sugar mill unit-1 District Dera Ismail Khan. Before implementation of efficient machineries bagasse consumption per ton sugar production was 2.35 Tons, Sugar losses in bagasse was 1.98 (pol % bagasse), steam economy was 48.2 % and bagasse saving was 70368 per season. After implementation of up to dated and energy efficient technologies the stated valves will be 1.75 Tons, 1.7 %, 35 % & 138613 Tons per season respectively. The overall energy saving is 25 % with a payback period of less than 03 years.

***Keywords*—** Energy Efficieny, Payback analysis, High Pressure Boiler & Turbine, Falling Film Evaporator, Fiberizer

***Abbreviation* —**Ton per hour (TPH), Ton Crushing per day (TCD), Million (M), Kilo watt (KW),Mega Watt (MW)

I. Introduction

The abrupt depletion of the conventional fuel resources around the world is sending shockwaves around the global energy markets. The fossil fuels are slated to concede their economic viability around the third quarter of the proceeding century. The lifecycle costs of the use of fossil fuels on the world climate are a matter of deep concern to the environmental conservation organizations. All the countries have started experiencing the adverse impacts of the climate change in form of loss to human lives as well as to the economies. This gloomy scenario has pushed the governments to look for means of abating the creep of the climate change in to their countries. Kyoto protocol was the first unanimous consensus of the countries to come up with ways of mitigating the fast recession of globe in to apocalyptic conditions. This struggle to limit the advancement of global average temperatures below two degrees over the preindustrial revolution era has brought the world to an agreement on restricting the utilization of fossil fuels.

Industry has remained the most intensive consumer of energy around the world for the past 50 years and is projected to remain the main user for the foreseeable future as shown in the figure 1. This trend suggests that the countries making more efficient and effective use of energy in industry are bound to achieve greater benefit for the same cost. The dynamics of global energy use are also undergoing a major paradigm shift. For the first time in history the energy demand of the developed world will be lower than the combined energy demand of the developing world [1].

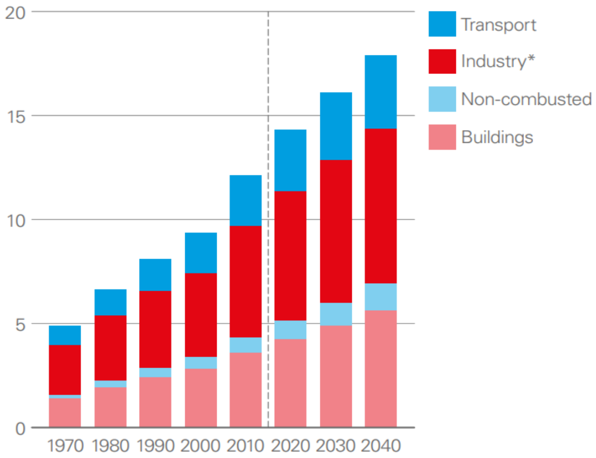


Figure 1. Global energy use projections by sector [2]

This is in part due to the growing population but more than that it is a product of the enhanced energy efficiency in the industries in developed countries. Developed world, on average, exhibit greater productivity per unit energy consumed than the developing economies. A significant factor behind this greater productivity is the improvement in the industrial energy efficiency in developed world achieved through extensive energy resource assessment.

The Paris Climate Agreement of 2016 [3] was a formidable achievement in the struggle for global climate conservation. The world leaders agreed to set stringent controls on emissions in their countries through incorporation of greater share of renewable energy resources in their energy mix. Renewable energy has already been growing at an appreciable pace throughout the world for the past decade. Among the new energy generation capacity addition the renewable have been continuously outpacing the conventional fuel installations. International Energy Agency (IEA)'s renewable energy report for the year 2017renewable energy projects with a cumulative addition of 167 GW far surpassed the additions from coal (57GW) and coal 29 (GW) as shown in the figure 2 [4].

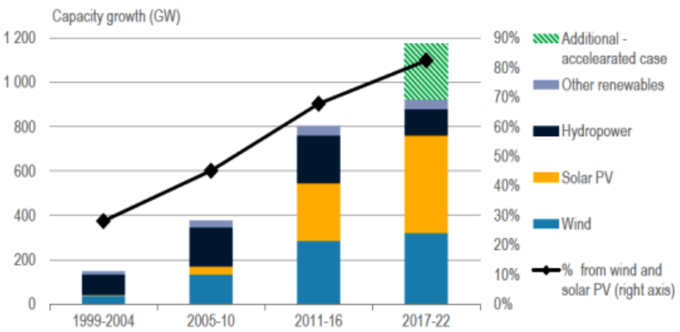


Figure 2. Renewable energy Projections 2017-22

There is however another resource that is even cheaper and less time consuming as compared to the conventional energy resources and renewable energy resources. The energy efficiency improvement in all energy consuming sectors has been proven more economically and temporally beneficial as compared to all the resources as shown in the figure 3. Energy efficiency enhancement in industry is considered a low hanging fruit which gives better return per unit time and capital investments.

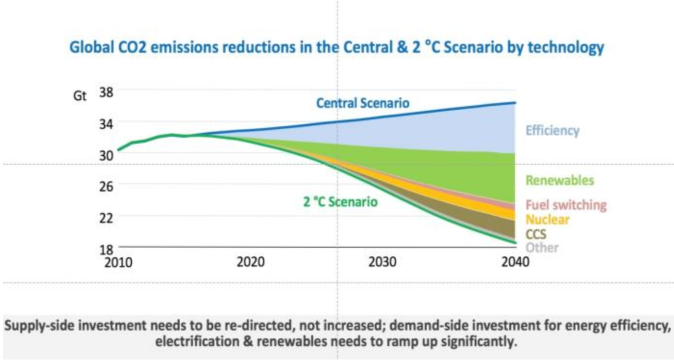


Figure 3. Energy efficiency as most effective resource for carbon mitigation and inhibiting climate change [5]

The story of Pakistan's energy woes is not hidden from anyone. For the past 15 years the country has been facing the brunt of energy shortages of varied extent and time. For a decade in between i.e. from 2008 to 2017 the energy shortages were at their most extreme. This inadvertently leads to negative impact on the economy. All around the world the economic growth is directly linked with the consumption of energy per capita as shown in the figure 4. If, for some reasons, the energy supply line is tented the economy suffers. Countries such as Taiwan, Korea, and China provide best avenues to test this relationship having achieved exemplary economic growth through energy use.

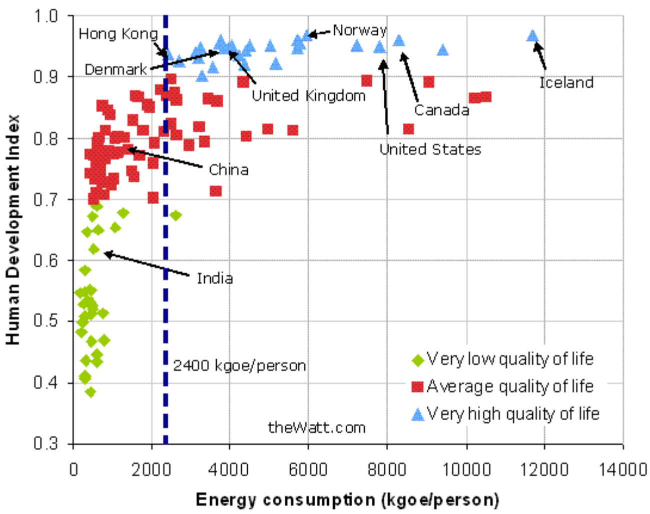
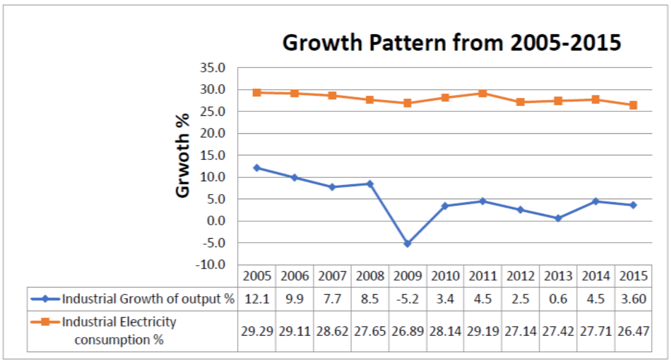


Figure 4. Energy consumption as a determinant of development [6]

In Pakistan the energy shortages have directly impacted the industrial growth of the country. The cycle is simple: the energy shortages and the subsequent interruptions in the industrial output resulted in a greater demand for the dwindling energy supply. This distortion in the demand supply cycle resulted in energy price hike further compounded by the stagnant energy efficiency capacity of the industries. This resulted in close to one fifth of the domestic manufacturing industry moving their production out of the country. The data for industrial energy consumption as percent of the national energy consumption paints a vivid picture of this dilemma when compared with the national industrial growth data as shown in the figure 5.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Industrial Growth of output %	12.1	9.9	7.7	8.5	-5.2	3.4	4.5	2.5	0.6	4.5	3.60
Industrial Electricity consumption %	29.29	29.11	28.62	27.65	26.89	28.14	29.19	27.14	27.42	27.71	26.47

Figure 5. Industrial growths vs. the electricity supply to the industry for Pakistan [7]

It is clear from the above graph that there is a direct link between the energy supply and the industrial growth of the country. The approximately 5 % of drop in electricity consumption is more a function of the dropping energy availability and the resultant rise in electricity prices during the period. This follows that the country could have achieved a far greater industrial and economic growth had the energy supply been stable. But there is another factor which could have significantly offset the shortage of electricity supply in the industries the apt utilization of the energy efficiency resource. The past 50 years of the industrial growth around the world suggests that there has been a decrease in the amount of energy utilized for achieving the same unit of economic growth as shown in the figure 1.6. As evident during the start of the 1990s the energy use for producing a unit of economic output was considerably greater than in the year 2015. Another point worth noticing is the low energy efficiency in the low income countries such as Pakistan.

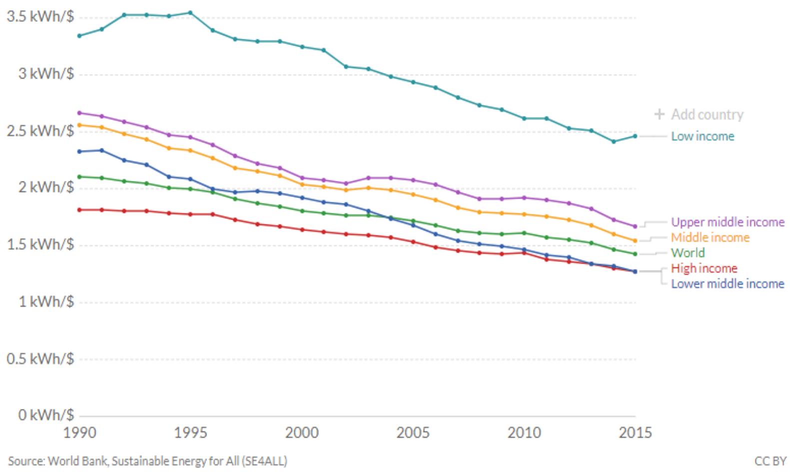


Figure 6. Comparison of the energy input to produce a unit of economic output over the years [8]

Accordingly Pakistan has also experienced a decreased level of energy efficiency in industry. This factor leads to lower competitiveness of the products at international level.

Sugar industry of Pakistan, the 6th largest contributor to the global sugar supply line, is one of the most energy intensive industries. Eighty fours sugar mills are currently operating in the country employing close to 300,000 people in the country and contributing 20 billion to the national tax regime. With all this the energy consumption in the industry has been largely absorbed by the captive power generation from the bagasse that is a byproduct of the sugar manufacturing. Considering the stressed energy supply line of the country and the global climate conservation problem it is of utmost importance that the energy efficiency resource assessment must be carried out for the industry to come up with energy savings opportunities [9].

II. CASE STUDY

Chashma sugar mills limited unit-1 has established in 1991. It is located in district dera Ismail khan Khyber Pakhtunkhwa Pakistan. It has total Crushing capacity of 12000 Tons per day (Avg 11500 TCD). It has 12 Mw Power Plant. Total Energy demand within the facility is 8 MW (Low pressure steam turbine & boiler) the major steam consuming areas are Mill House & Power house. The exhaust steam from turbine is de-supper heated at 130 degree centigrade before utilize in process house for heating of juice, syrup & Massecuite

A. *Energy Flow in the facility*

The sugar industry operational mode is seasonal. It operates from December to March for four months. In these operational days, the plant is powered by facility owned generated energy through cogeneration bagasse plants using bagasse of the production process. In off seasons, the facility is connected with WAPDA only using energy for residential colony and day to day office operation of mill. In general two major energy formats are used:

- Bagasse as primary source
- Steam as secondary source of bagasse
- Electricity as tertiary source from steam and used for facility operations.

In total bagasse about 76 % is burnt whereas remaining is saved and either compacted and sold out.

B. Steam Flow in the facility

The bagasse is used for steam generation in five different water tube Boilers. Two boilers are having 80 Tons/hr. steam production capacity; whereas other two have 40 Tons/hr. and one smaller with 12 Tons/hr. Total available steam capacity within the facility is 252 Ton/hr. Total steam demand of the factory is 230 TPH. The steam carrying thermal energy both serve process operations as well as power generations as shown in Figure 7. Consumers of steam are:

- Mill house
- Power house

The exhaust steam from the Mill & Power House is utilized in Process house for Heating juice, Condensate is then return to Boiler.

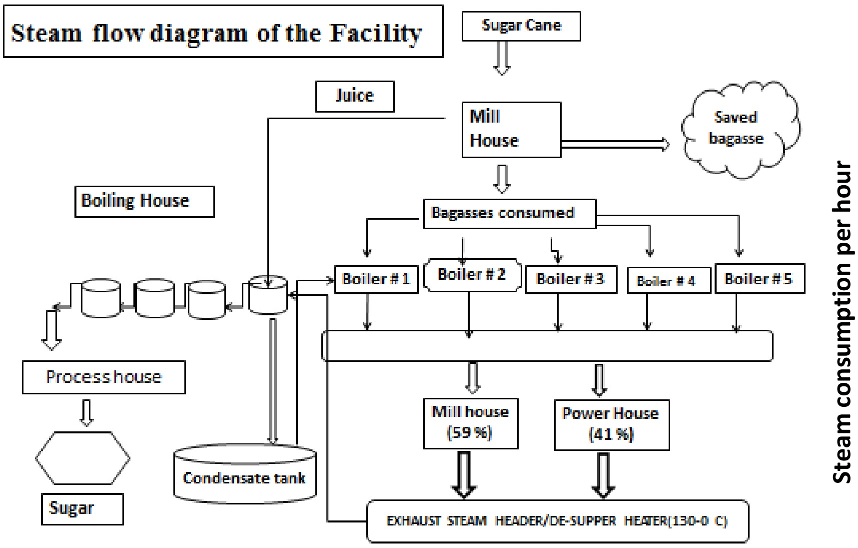


Figure 7. Steam flow within the facility

C. Boiler House Energy Flow

Boiler house function to provide steam for electric power generations and milling operation. The facility owned five boilers out of which four boilers are operational and one is stand by. Total designed load 252 Ton/hr. as given in table I and as shown in figure 8.

TABLE I. DESIGN AND OPERATIONAL DETAILS OF BOILERS

Description	Design load (TPH)	Running load (TPH Avg)	% Load
Boiler -1	40	36	90
Boiler -2	40	37	92.5
Boiler -3	80	77	96.2
Boiler -4	80	78	97.5
Boiler -5	12	Stand by	
Overall load on boiler house	252	228	95

TABLE II. SECTION WISE OVERVIEW OF STEAM CONSUMPTION IN THE FACILITY

Description	Actual Steam consumption (TPH)		% steam consumption
Mill House Tendam-A	72	135	59
Mill House Tendam-B	63		
Power House	93		41
Total	**228**		**100**

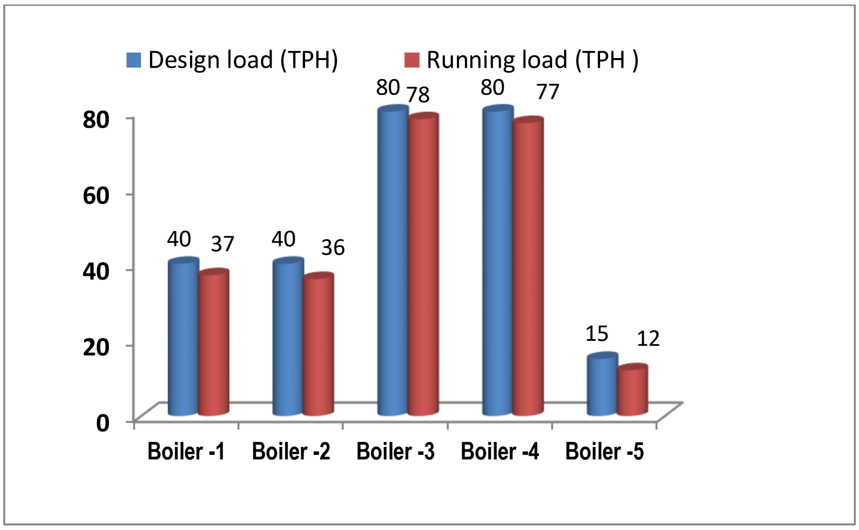


Figure 8. Comparative Investigation of Design Vs. Operational Load of boiler house

The consumption of steam is further elaborated in Table II and Figure 9 where it can be observed that mill house and power house are the two main consumers of steam generated

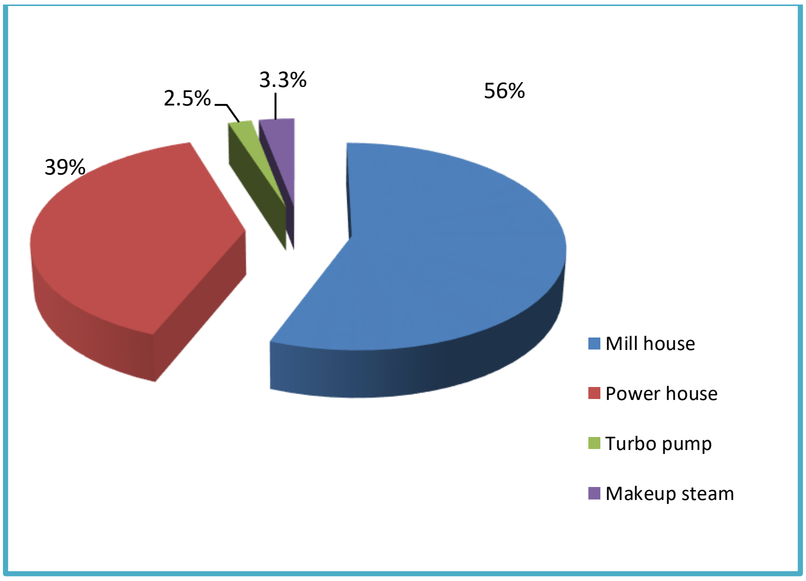


Figure 9. House wise steam consumption in the facility

D. *Power House energy Flow*

Power House is one of the SEUs considered for investigation. It mainly comprises of four back pressure Impulse turbine having total capacity of 12 MW. The system requirements stand around 8.1 MW whereas one turbine of 2MW is held for stand by purposes to facility during emergency hours as shown table III.

TABLE III. INSTALL & RUNNING LOAD OF POWER HOUSE

Description	Installed Power (MW)	Running Power (MW)	% Load
Turbine-1	02	Stand by	-
Turbine-2	02	1.6	80
Turbine-3	04	3.2	80
Turbine-4	04	3.3	82.5

Overall load on power house	**12**	**8.1**	**81**

E. *Electricity Consumption Patterns*

The electricity evacuated from power house to feed various sections and processes along with their accessories requirement as shown in Table IV. Process house is the major consumer followed by mill house and boiler house.

TABLE IV. OVERVIEW OF DEMAND IN DIFFERENT SECTION OF THE FACILITY

Sr. #	Description	KW	% load
1	Process house	3170	39
2	Mill house	2175	26
3	Boiler house	1280	16
4	Injection and spray pumps	1175	15
5	Colony	300	4
	Total	**8100**	**100**

III. METHODOLOGY

I have adopted 10 steps methodology:

Step-1. Plan and organize, Walk through Audit, Informal Interview with Energy Manager, Production / Plant Manager

Step-2 . Conduct of brief meeting / awareness program with all divisional heads and persons concerned

Step-3 Primary data gathering, Process Flow Diagram & Energy Utility Diagram

Step-4. Conduct survey and monitoring

Step-5. Conduct of detailed trials / experiments for selected energy guzzlers

Step-6. Analysis of energy use

Step-7. Identification and development of Energy Conservation (ENCON) opportunities

Step-8. Cost benefit analysis

Step-9. Reporting & Presentation to the Top Management

Step-10. Implementation and Follow-up

IV. DEVELOPING BASE LINE SCENARIO OF MILL HOUSE

There are two Milling Tandem, T.A & T.B each having 04 No's Crushers with a crushing capacity of 6000 & 5500 tons per day respectively. Cane passes through crushers, juice extracted and send to Boiling house for further process to produce refine sugar. Back pressure impulse turbine is used to drive the crushers. After juice extraction bagasse is send to Boiler house and is used as a fuel for steam generation. About 76 % bagasse burnt and the remaining 24 % saved for selling out. Significant energy saving opportunity exist in mill house, therefore mill house is our prime focus in this case study to increase the profitability of the facility and reduce losses.

A. *Bagasse Saving calculation of the existing system*

Crushing rate = 11500 TCD = 479 TPH (Tandem-A 6000 & Tandem-B 5500 TCD)

At normal practice sugar mill can produce 32 % bagasse on Cane.

Total Bagasse produced = 479 x 0.32 = 153 TPH Total Steam demand of Mill house both tandem =135 TPH (Tandem-A =72 TPH & Tandem-B= 63 TPH

Total Electric load of Process house, Boiler house & Colony = 8.1 MW

Steam demand = 8.1 x 11.5 = 93 TPH (turbine steam consumption = 11.5 kg/kw/hr.)

Total steam demand of the existing system = 228 TPH Steam to bagasse ratio of the existing boilers = 1.96 (Avg valve reported during previous 03 season

Bagasse consumption at 1.96 Steam to bagasse ratio = 228/1.96 = 116 TPH

Total Bagasse saved = 153 – 116= 37 TPH Bagasse saved per season at 80 % work hours = 0.8 x 37 x 24 x 120 = 85,248 Tons

Steam % on cane of the existing Rising film Robert type Evaporators = Total steam(TPH) / Total Cane crushed (TPH) = 228/479 x 100 = 48 %

Sugar production @ 10.5 % Avg recovery = Total crushing

x recovery % = 479 x 10.5 % = 50 Tons

Sugar production per season at 80 % working hour s = 0.8 x 50 x 24 x 120 =115200 Tons

Bagasse consumption per ton sugar production =116 /50 = 2.32Tons

B. *Developing Energy Efficient Scenario*

Scenario # 1

i. Sugar Saving:

Crushing rate = 11500 TCD = 479 TPH

Total Bagasse production = 353 TPH (at 32 % on cane) Sugar production = 50 TPH (at 10.5 % avg recovery) Pole before improvement = 1.98 (Avg of the previous 03 years of both tandem)

Bagasse Pole after improvement will be = 1.7 % Pole % saved = 1.98 – 1.65 = 0.33% of bagasse Sugar saved = 50 x 0.33 % = 0.165 TPH

Total sugar saved per season = 0.8 x 0.165 x 120 x 24 = 380 Tons (Pole is pure Sucrose/Sugar)

Amount saved at Rs.90/kg = 380000 x 90 = Rs. 34,200,000/- (Sugar current rate without sale tax = Rs.90/kg)

ii. Bagasse Saving:

The following calculation will best explain the total bagasse saving obtained by applying the recommended ECMs (Energy conservation measure) in Mill house. Steam Consumption of Mill House in the improved system is calculated below

Total electric load of Mill House (TA & TB) in the improved system = 16 MW (Tandem-A =8 MW, & Tandem-B= 8 MW.

Total Steam demand to generate 16 MW electric power = 16 X 6 =96 TPH (steam consumption of hp boiler = 6 kg/kwh)

Total load of Process house, Boiler house & Colony = 8.1 MW Steam demand = 8.1 x 6 = 49 TPH

Total steam demand of the improved system = 145 TPH Total bagasse consumption 145/2.4 = 60 TPH (at 2.4 steam to bagasse ratio)

Extra bagasse saving in the improved system = 116 – 60 = 56 TPH Extra bagasse saving per season = 0.8 x (56 x 24 x 120) = 129,024 Tons (36 %)

Amount saved @ R.S 5500 per ton =129,024 x 5500 = R.S 709,632,000 /- Per season

Total saving = sugar + bagasse =34,200,000+709,632,000= R.s 743.2 Million Per season

Total estimated budget of the said project (scenario # 1) = R.s 1000 Million /- Payback period = 1.5 Season Bagasse consumption per ton sugar production =60 /50 = 1.2 Steam % on cane = 145/479 x 100 = 31 %

C. System Optimizations

At present there are two milling Tandem, tandem-A &tandem-B each having 04 No's mills which are drive by back pressure impulse turbine which consumed steam. In this case study I have developed two scenarios in order to save energy (Bagasse).

Scenario # 1:

Recommendation

- Replacement of drive units i.e. Turbine by VSD Motors
- Replacement of Unigrator with Fiberizer
- Installation of 5th Mill
- Replacement of Robert type Evaporator by Falling film Evaporator to increase overall Heat transfer co-efficient & reduce steam economy
- Installation of 01 No high pressure boiler under the following specification

H.P Boiler (65 Bar, 160 TPH & 480-490 Degree Centigrade)

- H.P non condensable steam turbine 26 MW for VSD Motors that is to be installed in Mill house for Cane preparation and Cane crushing mechanism

By doing such practices Juice extraction will be increased i.e. Sugar losses in bagasse will be minimized. Preparation index (P.I) will be improved (90 % +).Bagasse moisture will be decreased. Extra Bagasse will be saving for selling out. Steam % on cane will be reduced.

D. Total Additional revenue and Payback analysis (Scenario # 1)

The total revenue generated by the implementation of recommended ECMs along with the payback analysis are listed in the below table V.

TABLE V. TOTAL SAVING & PAYBACK ANALYSIS (SCENARIO # 1)

Description	Qty (Tons)	Unit Price (R.s)	Additional revenues
Sugar saving after Reduction in pol % bagasse	380	90/kg	34.2Million
Extra Bagasse Saving after Installation of VFD in Mill House & HP Power house	129,024	5500/ton	709.6 Million
Total Additional revenues			**743.8 Million**
Total estimated budget for the project scenario # 1			**1000 Million**
Payback analysis			**1.4 Seasons**

V. DEVELOPING ALTERNATE SCENARIO FOCUSED ON DSM SCENARIO # 2 COGENERATION

A. Recommendation

01 No High Pressure Bagasse fired water tube Boiler having Steam capacity = 160 Ton per hour,Temperature = 489-490 degree centigradeLive Steam Pressure = 65 bar, Steam to bagasse ratio = 2.4,

01 No high Pressure condensable steam turbine with the given specification, Generation capacity = 26 MW, Steam consumption 6 kg/kwh (recommended by manufacturer), Live steam temperature = 489-490 degree centigrade Live Steam Pressure = 65 bar

i. Saving via Cogeneration :

Steam consumption of high pressure steam turbine 26 MW = 6kg/kWh

Total steam consumption = 26 x 6 =156 Tons per hour = 120 x 24 =3744 tons per day

Total bagasse consumption @ 2.4 steam to bagasse ratio = 3744 /2.4 =1560 tons per day

Extra bagasse saved after improvement = 129,024 Tons per season(calculated in scenario #1)

Number of days the given high pressure steam turbine generate electricity by utilizing the saved bagasse = 129,024/1560 = 83.7 days (12 Weeks)

At 80 % load 26 MW Turbine would produce Power = 16 MW

Electricity provide to grid = 16000 x 24 x 83.7 = 41,783,040 kWh

Price of single industrial unit = R.s 15 per kWh Total revenue generated = 626.7 Million PKR

It means that if we used the saved bagasse as a biofuel within the facility it will generate 41,783,040 kWh electrical energy which is to be sell out to grid by the mill, generate a total revenue of 626.7 Million PKR.

VI. Screening Tests of Recommended ECMS

After detail analysis and calculation of the recommended up to date and energy efficient technology the following results will be obtained table VI and table VII.

TABLE VI. Overview of the result for the present Operation and Future Scenarios

Description	Present System	Improved system
Crushing (TCD)	11500	11500
Pol % bagasse	1.98	1.65
Preparation index %	80-82	90-92
Steam % on Cane	48	31
Bagasse consumption	76 %	40 %
Bagasse saving (Ton)	24 %	60 %
Fuel/bagasse Consumption per ton Sugar production	2.32 TPH	1.2 TPH
Extra bagasse saved in the improved system per season (Tons)		**129,024 (36 %)**

ii. Sugar Saving (same as in case of scenario # 1)

Crushing rate = 11500 TCD = 479 TPH

Total Bagasse production = 353 TPH (at 32 % on cane)

Sugar production = 50 TPH (at 10.5 % avg recovery)

Pole before improvement = 1.98 (Avg of the previous 03 years of both tandem)

Bagasse Pole after improvement will be = 1.65 %

Pole % saved = 1.98 – 1.65 = 0.33% of bagasse Sugar saved = 50 x 0.33 % = 0.165 TPH

Total sugar saved per season = 0.8 x 0.165 x 120 x 24 = 380 Tons (Pole is pure Sucrose/Sugar)

Amount saved at Rs.90/kg = 380000 x 90 = Rs. 34,200,000/- (Sugar current rate without sale tax = Rs.90/kg

Total amount saving = Sugar + Electricity = 34.2 + 626.7 = R.s 660.9 Million

Total estimated budget for this project = R.s 1000 Million Payback period = 1.5 Seasons

TABLE VII. Total saving & payback analysis (Scenario # 2)

Description	QTY	Additional revenues
Unit of electricity saved in case of cogeneration from bagasse	41.78 Million kwh	626.7 Million @R.s 15/Unit
Sugar saved as in case of scenario # 1	380 tons	R.s 34.2 Million @ R.s 90/Kg
Total Additional revenues scenario # 2		R.s 660.9 Million
Total estimated budget for the project scenario # 2		1000 Million
Payback period scenario # 2		1.5 Seasons

Concuslion

Provision of energy at affordable prices is vital for industrial productivity. Being centric to energy crises, Pakistan's industrial units suffer adversely as result of high prices, energy insecurity and load shedding. Sugar Industry though uses of the available bagasse for power generation and steam utilities, however, the recent research studies carried in developing countries, highlights needs of assessing energy resource potential in sugar industries. This research work addresses the research opportunity available in assessing real time energy conservation and energy efficiency potential available in Chashma Sugar Mills. The research based on standard practice reviewed the energy and material flows in the facility. Based on Significant Energy Uses concepts, further detailed investigations aligned with ASHARE Level Three audit were carried to assess the available energy conservation measures, energy efficiency opportunities, system optimizations possibilities and energy efficiency resource prioritization based on economic and financial indicators like payback period, IRR etc. The overall outcomes have been normalized using Energy Performance Indicators like steam (bagasse) consumption/ton sugar production has been used.

It has been revealed that mill house and power house are two main SEUs responsible for approximately 59 & 41 % steam consumption respectively. The research recommends usage of high pressure water tube Boiler and high pressure steam turbine. With this setup steam to bagasse ratio increases also steam consumption of high pressure turbine is low (6kg/kWh) as compared to low pressure (11.5 kg/kWh). In the present system approximately 24 % bagasse saving and 76 % consumed while in the improved setup 60 % bagasse will be saved and the remaining 40 % will be consume. Thus the improved system will add 36 % extra bagasse to the facility. This whole project will cost 1000 Million PKR with a payback of 1.4 Season in case of scenario-1 and 1.5 Season in case of scenario-2

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