1.1 SUGARCANE AN ENERGY CROP OR A MINI 'DAM'

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Abstract

Sugarcane is an important cash crop for growers and crop is grown to meet the sugar needs of the country. What to speak of sugar whole plant part the cane stalk, tops, all green and dry leaves are the sources of energy. The energy benefits drawn from the crop are multidimensional. This energy is generated during three phases of its products and byproducts formation. During cane crushing, 30 percent of cane weight is left as bagasse, which as a source of steam production in boiler, becomes the main parameter of energy. This steam, not only meets the mechanical and electricity requirements of all the sugar plant, enough bagasse is saved to generate surplus electricity for supply to National Grid. This is what we call energy power equivalent to a Mini Dam. The second source of energy is the molasses separated from massecuite during centrifugal process of sugar. This molasses is the source of ethanol production in the distillery, to the tune of 235 liters per ton of molasses. In the modern world this bioethanol is being largely utilized to replace gasoline in a fixed blended ratio. Due to hike in petroleum prices ethanol has taken the position of biofuel for transport vehicles, saving billions of foreign exchange. The third phase appears during ethanol formation. During this process a waste product spent wash is obtained which, on anaerobic digestion, produces biogas in the form of methane and carbon dioxide. This methane meets 70 percent energy requirements of distillery plant and the remaining energy needs to be fulfilled by bagasse combustion. The CO_2 gas is supplied to beverage industry.

As an example, the energy potential of a 12,000 TDC capacity operating sugar mill for 120 days, includes production of 151,200 tons of refined sugar @10.5% recovery, and generation of 31 MWh of electricity from bagasse, during 120 days of milling operation and 23.75 MWh during extended 104 days offseason working. This is what we call energy equivalent to a Mini Dam. The byproduct 64800 tons 'molasses' produced during the process has the potential to produce 15.228 million liters of ethanol in an attached distillery. Though of course this can be converted to 10.152 million liters biofuel. This is a substantial quantity to replace the imported gasoline for light vehicles. In addition, 3 MWh power requirements of an associated 150,000 liters capacity distillery plant, are met from the biogas generated from anaerobic digestion of waste material 'spent wash' released during ethanol distillation. These are live energy release instances of one sugar mill and the energy calculation for 79 working sugar mills in the country must be surprising. Besides these energy parameters, additional benefits are extracted from waste products 'press mud and spent wash', which can be utilized as most valuable organic fertilizer for application in cane fields. This organic fertilizer substitutes the full needs of N, P and K contents required by cane crop. It is recommended that the government should chalk out National Policy to utilize the full energy potential of the crop to generate electricity as well as produce biofuel. Sugar mills should also have a strict policy to utilize press mud and spent wash for crop and land development only.

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Introduction

Sugarcane is an important cash crop for grower's community and the crop is grown to meet the sugar needs of the country. What to speak of sugar whole plants parts the cane stalk, tops and all green and dry leaves are the source of energy. Sugarcane leaves trap solar radiation and transform this energy into chemical energy through photosynthetic process which is stored in cane stalk as sugar. This energy is being utilized in one form or the other. The crop biomass is utilized to provide steam energy to run the factory, and to generate electricity; while cane juice is utilized to produce energy as sugar, as well as biofuel. As for how? And to what extent the energy is generated, are the topics of this chapter.

An over view of cane crop and Pakistan Sugar Industry

Average cane yield of Pakistan is 69.25 tons per hectare, while potential exists around 75 tons. During 2021-22 crushing season sugar industry showed a sugar production level of 7.876 million tons with 9.85 % sugar recovery. Sugar industry crushed 79.95 million tons cane and produced 7.88 million tons sugar with average recovery of 9.85%. The industry has the potential to manufacture over 8 million tons sugar per crop season with average recovery of 10.5 %. Besides sugar, a number of distilleries have been installed alongside sugar industry in the country, which produced 3.6 million tons molasses during the reported period. Present status of sugarcane and its products in Pakistan and its provinces is shown in **Table-1.**

Table-1: An over view of sugarcane and sugar industry of Pakistan and its provinces during 2021-22*

Particulars	Pakistan	Punjab	Sindh	KPK
Cane area '000' ha.	1,266.1	869.0	289.5	106.8
Cane production '000' tons	87,672.0	63,000.0	18,974.3	5,662.4
Cane yield 'tha^{-1}	69.25	72.50	65.54	53.02
No. of sugar mills.	79	41	32	6
Cane crushed - tons	79,954,711	53,316,780	22,277,208	4,360,723
Sugar produced - tons	7,876,288	5,132,737	2,291,467	452,084
Sugar Rec. %	9.85	9.63	10.29	10.37
Molasses produced - tons	3,597,962	2,399,255	1,002,474	196,232
Molasses %	4.50	4.50	4.50	4.50

- Anon, 2022.

On milling cane stalks, in the factory, juice is extracted which undergoes various boiling, clarification, evaporation, condensation, and crystallization processes for sugar manufacture. During these operations some secondary products **'Bagasse'** and **'molasses'** are obtained which form the basis of power generation and biofuel production. Some waste products like filter press cake, spent wash, methane and CO_2 gas are also obtained which have their own economic value.

A cane crop yielding 100 tons clean cane per hectare when crushed in a sugar factory in general produce the following products and by-products (Paturao, 1988)**.**

Cane: **100** tons

Bagasse: **30** tons (50% moisture) – a power source **used as fuel to produce steam.** This steam is utilized for various factory operations as well as electric power generation for various sugar mill's operation; more or less 10 tons may be saved for power export during off season.

Filter press cake: **3** tons (A waste product)

Water: **63** tons: this water is evaporated as steam during boiling of cane juice, and is Recycled/utilized for use in various factory operations as well electric power Generation.

Sugar: **10** tons (at an average sugar recovery of 10 %)

Molasses: **4.5** tons

Production of 30 tons bagasse and 4.5 tons of molasses from a 100 tons crop appears to be a small quantity but the quantum of energy to be released is miraculous. On the whole one ton of sugarcane typically contain the same amount of energy as 1.2 barrel of petroleum (Leal, 2010); And, the quantum of energy in cane, crushed in one sugar mills, is equivalent to the energy recovered from a mini Dam. Some technology is to be applied to extract this energy from cane.

Sugarcane energy parameters

1. **Sugar:**

Cane stalks, after harvest in field, are brought to the factory for crushing. Cane juice contained in cane stalks is extracted during milling operation, leaving aside fiber extract called '**bagasse'**. The bagasse is utilized for combustion to produce steam required for boiling the juice. The **steam** so produced during boiling phase is also utilized in various passes of clarification, evaporation, concentration, and crystallization. The part of steam energy is also utilized for **electric generation**. In the last phase of crystallization, **molasses** is separated aside and the end product **'sugar'** is bagged and stocked.

The sugar itself is an energy product for which cane crop is grown. Advances in technologies have highlighted the miracles of bi-products 'Bagasse and Molasses' that value of crop has increased manifold. During clarification process a waste product **press mud** is also obtained.

2. **Bagasse**:

It is the fibrous residue left after extracting juice from cane in the mills. One ton of cane stalks on crushing leave aside about 300 kilogram bagasse with 50% moisture. Bagasse is an excellent raw material that on burning release heat having a calorific value of 2300 Kcal/Kg (Saleem Shah, 2014). By the combustion of the bagasse in boiler's furnace, steam is produced, this steam energy is used in various operations of milling, juice clarification, evaporation, concentration and then crystallization to produce the end product "Sugar".

Power generation

The energy contained in cane plant is much more than simple process of sugar production. The steam is also utilized to run generator to produce required electricity in the factory. As for power generating capacity of bagasse, it has been worked out that one ton of bagasse produces two tons of steam and five tons of steam generates 1 Mwh electricity. It means 2.5 tons of bagasse would produce 5 tons of steam that generate 1 Mwh electric power (Isabirya *et.al*, 2013; Narijan et al, 2005). Due to this very established equation, bagasse is considered the world wide renewable source of generating energy.

The quantum of energy released depends on the efficiency to which the bagasse is utilized in the factory. 1 kWh electric generation require about 2 Kg of bagasse (Harijan etal, 2008), the same magnitude of electricity can be generated by 1.6 Kg of bagasse (Bhattacharyya and Thang, 2004) In most of the sugar mills in Pakistan electricity is generated to meet their own power needs. Conventional boilers, having pressure of 23 bars with temperature 350^0C, produce 2–2.2 tons of steam from one ton of bagasse (Harijan *etal*, 2008). They consume 450-500 kg steam and generate hardly 10-20 kWh electricity per ton of cane. The High pressure boilers with temperature of 500^0C, can generate 2.4 ton steam/ton bagasse **(**Munir, etal 2004)**.**

With some better process house working efficiencies, steam consumption can be reduced to 340 Kg per ton of cane and with adoption of 82 bar/480°C steam boiler, a minimum surplus power of 100 kWh per ton of cane can be achieved (Kamate and Gangavati, 2009). In India, modern cogeneration units of sugar mills are reported to operate with boilers having live stream parameters as high as 45-80 bars and over 450 ^{0}C, generate electricity in the range of 115-120 kWh per ton of cane (Kamate and Gangavati, 2009). Now the boilers of still higher capacity and pressure around 110 bar are being marketed. The combined use of high pressure boiler with condensing steam extraction turbine, electric drives instead of steam drives and other steam reduction measures will result in even more surplus power.

The technology to produce energy through bagasse has now been greatly revolutionized. Still further technology has been explored, wherein biomass integrated gasifier/gas turbine co-generation (BIG-GT) and biomass gasifier combined with steam injected gas turbine cogeneration (BIG-STIG) are considered as potentially promising future technologies. These technologies are capable of generating energy up to 270-275 kWh per ton of cane (Kamate and Gangavati, 2009). Thus the new technology help save enough bagasse to generate surplus electricity for supply to the National Grid.

Electric Power Production Potential for a 12000 TCD Sugar Plant

The energy release potential of sugarcane can be illustrated from a 12000 TDC sugar plant (Table-2); details shown in the Annexture. It has been worked out that a sugar mill having 12,000 TDC capacity equipped with a 110 bar pressure boiler would generate 31 MWH surplus electricity during 120 days of its operation. The same plant will save enough bagasse to generate 23.75 MWH electricity during off season duration of 104 days. ***This is what we call a Mini Dam***. At the prevailing rates this energy plant would yield an income of Rs. 1.786 billion. This off season duration can be considerably extended if cane trash, rice straw, cotton sticks or coal is admixed with bagasse in some ratio.

Electric generation in a 12000 TCD sugar Mill

Crushing capacity tons per hour:	500
Bagasse available for Cogeneration (excluding bagacillo):	146.5
Power generation during the season	
Sugar mills operating days:	120
Total power generation (KWH):	47340
Power consumption of sugar mill (KWH):	11500
Auxiliary consumption (condensing extraction turbine+ back pressure turbine):	4742
Electric power exportable to Grid:	31098
Off season electric generation	
Off season operating days:	104
Gross power generation (KWH):	26500
Power consumption in sugar mill (KWH):	500
Auxiliary power consumption:	2252
Exportable Power (KWH):	23748
Electrical energy export during operating season: (milliom units)	89.56
Off season energy export: (million units):	59.27
Total energy export: (million Units	148.87
Current Tariff on bagasse based electricity:	Rs. 12/KW
Total income (billion);	Rs. 1.786

During 2021-22 crop season 79.954 million tons of cane was crushed in sugar mills. When all the sugar mills are given appropriate incentives, Pakistan sugar industry has the potential to safely generate 2500 MWH electricity and above all this would be the cheapest source that can be installed in shortest possible time. Cane harvesting, including winter and post winter days, is the period when hydroelectricity in Pakistan is markedly reduced due to dearth in rivers water. If this source is manipulated, would be a great support to National power generation projects.

Bagasse based energy units in Pakistan

In Pakistan during 2021–22, seventy nine sugar mills were in operation, and the cane crushing capacity of these mills range between 8,000 to 28,000 TDC. Unfortunately, except a few mills most of the factories have traditional equipment's with small capacity boilers. The sugar mills registered to produce electric power through cogeneration are listed in **Table-2**. So far 27 sugar mills are reported to have installed energy units based on sugarcane bagasse, having a total power generating capacity of only 900.11 MWH. If it is managed to collect trash for combustion along with bagasse, will greatly help extend the operating days of the energy plant. At the same time will assure supply of trash free clean cane to the factory.

Table-2 : Power generating capacity of some completed and ongoing

Projects in sugar mills of Pakistan*.

S.No.	Name of Power Plant	Capacity MWh
1	Alliance Power (Pvt.) Ltd.	30
2	Bahawalpur Energy Ltd, Ashraf Sugar Mills	31.20
3	Al-Moiz Industries Ltd., Dera Ismael Khan	36
4	Chenar Energy Ltd.	22
5	Chiniot Power Ltd.	57
6	Etihad Power generation Ltd.	74
7	Faran Power Ltd	26.50
8	Ghotki Power (Pvt) Ltd.	45
9	Habib Sugar Mills Energy Ltd.	26.50
10	Hamza Sugar Mills Ltd.	15
11	Hamza Sugar Mills Ltd. Unit II	30
12	Hunza Power (Pvt.) Ltd.	49.80
13	Indus Energy Ltd.	31
14	Ittefaq Power Ltd.	28.11
15	JDW Sugar Mills Ltd. Unit II	26.35
16	JDW Sugar Mills Ltd. Unit III	26.35
17	Kashmir Power (Pvt.) Ltd.	40
18	Mehran Energy Ltd.	26.50
19	Mirpur Khas Energy Ltd.	26
20	RYK Energy Ltd.	25
21	RYK Mills Ltd. (RYKML)	30
22	Shahtaj Sugar Mills Ltd.	32
23	Shaikhoo Power (Pvt.) Ltd.	30
24	Sadiqabad Power (Pvt.) Ltd. JDW Sugar Mills Ltd.	15
25	Thal Industries Corporation Ltd. Layyah Sugar Mills	41
26	Tay Powergen Company (Pvt.) Ltd.	30
27	Two Star Energy (Pvt.) Ltd.	49.80
Total		900.11

*NEPRA (National electric power regulatory Authority)

3. Molasses

Molasses is mother liquor left after crystallization of cane juice. It is thick viscous syrup and is released during centrifugal process of sugar in the sugar mill. During this process refined sugar is separated from mesquite, bagged and stocked in store house, while the by-product ‘molasses’ is stocked in cemented/steel tanks. The molasses is produced @ 4.5% by weight of cane crushed in the factory. Though molasses appears to be a small fraction of cane but is of great economic significance. It is processed in distilleries to produce ethanol that has occupied the international market as biofuel.

Ethanol:

Molasses contain a large fraction of fermentable sugars. It is diluted with three times water and allowed to ferment in the presence of yeast culture either by Batch or Continuous process of fermentation. On an average 22 to 25 percent ethanol is recovered from the molasses (Sukumaran et al, 2017). In another report ethanol recovery varies from 240 to 270 liters per 1000 Kg of molasses (Rashid and Altaf, 2008). To be on safe side, 235 liters ethanol per ton of molasses may be assumed a general average.

Bioethanol is also a form of renewable energy and has proved to be the best alternative of gasoline. Ethanol fuel has a gasoline gallon equivalent value of 1.5 i.e. to replace the energy of 1 volume of gasoline, 1.5 times the value of bio-ethanol is needed (Anon, 2021). With huge hike in petroleum prices bio-ethanol has gained great economic importance as biofuel.

Keeping in view the day by day depleting reserves of fossil fuels, attention is being diverted to look for renewable energy resources from crop biomass or biofuel. From amongst various field crops and wild plants, the energy demand of mankind can be met from some field crops like sugarcane, sugar beet, sweet sorghum, corn, and wild plants like Witch grass and Cassava (Robert, 2006). The bioethanol yield potential of some selected crops is given in **Table-3**.

Table-3: Bio-ethanol yields per acre from selected crops

Crop	Fuel yield - gallons
Witch grass	1150
Sugar beet (France)	714
Sugarcane (Brazil)	662
Cassava (Nigeria)	410
Sweet sorghum (India)	374
Corn (USA)	354

A number of countries have adopted these crops as renewable energy sources to minimize or replace the use of fossil fuel. As for sugarcane, on the whole one ton of sugarcane typically contain the same amount of energy as 1.2 barrel of petroleum (Leal, 2010); For that matter sugar industry appears to be the best entrepreneur where potential exists for power generation from crop biomass and biofuel to meet part of national energy requirements.

Ethanol is blended with some fraction of gasoline which is being widely used in Brazil, USA, China, Europe and several other countries including India. Gasoline is now being substituted by bioethanol in various blends of E10, E20, E30, E50, and even more. Lower blends are mostly used in light vehicles and cars. Brazil blend with 26% ethanol; India has already adopted E10 and is now planning to install system for E20.

It is learnt that in Brazil, fifty percent of the light vehicles and car drives are ethanol based (Basso, 2011). Almost 50 percent of sugarcane industry in Brazil is ethanol based distilleries; sugarcane is crushed and the juice is directly fermented to produce ethanol alone. The other situation is to produce sugar and ethanol. Priority is determined by market prices favoring production of sugar or ethanol. In terms of biofuel one ton of sugarcane produces 80 - 90 litters of alcohol (Luiz, 2019), thereby a cane yield of 70 tons per hectare produces about 6470 liters of alcohol (Goldemberg and Guardabassi, 2010). While in the case of combined products one ton of sugarcane produces about 100-120 Kg of sugar and 45 Kg of molasses which would be yielding more or less 11 liters of ethanol.

The present day market economy is drastically disturbed due to price hikes of fossil fuels the petrol/diesel. For a country like Pakistan situation is still more precarious as Pakistan mainly depends on thermal based energy from fossil fuel combustion and liberal use in transport of goods and vehicles. This is a great burden on foreign exchange reserves as over 65% of these energy sources are to be imported (Anon,2020). Recent price hikes on imported fuel has further aggravated the situation and should be eye opener to look for alternate sources for energy generation. The molasses or the ethanol produced locally are mostly exported. During 2020-21; 405.6 million liters of alcohol was exported that could have saved billions of foreign exchange if otherwise used as biofuel.

Biofuel production from a 12,000 TDC Plant

Considering a sugar mill having cane crushing capacity of 12,000 TCD and that works for 120 days, would produce 64800 tons molasses at the rate of 4.5%. And this molasses @ 235 liters ethanol a ton, is capable of producing 15.228 million liters of ethanol. This volume of ethanol can substitute the import of 10.152 million liters of petrol which is likely to earn Rs. 2.233 billion. This is the case for one sugar mill.

Biofuel production from a12000 TCD Plant

Cane crushing capacity: (tons):	12,000
Operating days:	120
Molasses production @ 4.5%: tons	64800
Ethanol @ 235 liters per ton of molasses: (Mill. liters)	15.228
Petrol to be substituted by ethanol: (Mill. liters)	10.152
Cost price @ Rs. 220/liter: (billion)	2.233

Biofuel production from the molasses produced in Pakistan

Total molasses production (million tons):	3.598
70 % molasses to be used for ethanol production:	2.519
Ethanol production @ 235 liters per ton of molasses (mil. Liters):	591.87
Ethanol converted to biofuel (mil. Liters):	394.58
Value of expected biofuel @ Rs. 220/liter (billions)	86.801

1.1.1 During 2021-22 crushing season, 3.598 million tons molasses was produced in Pakistan sugar mills. If seventy percent of this molasses is converted to ethanol in distilleries, 591.87 million liters of ethanol would be produced. At the petrol equivalent factor of 1.5, this quantum equals 394.58 million liters of petrol. The value of this biofuel amounts to Rs. 86.801 billion. It indicates the potential of Pak sugar industry to produce biofuel and that can substitute gasoline in the country. The economist and planners may sit to work out the saving of billions of foreign exchange.

1.1.2 During fermentation process for the production of ethanol, a waste product 'spent wash' is also produced at the rate of 12 liters per liter of ethanol produced. It is utilized for biogas generation and also as organic fertilizer to field crops.

4. Biogas generation.

In a molasses based distillery plant a waste product 'spent wash' is separated during ethanol distillation process. This is of great value to the distillery plant itself. With the help of enzymatic anaerobic digestion of spent wash, Biogas is generated that include around 70 % methane gas and 30 % carbon dioxide gas. This biogas is the main energy source of this plant. Almost seventy percent energy requirements of distillery plant are met from the Biogas and the remaining needs are fulfilled by bagasse combustion to produce steam energy. For a 150,000 liters capacity ethanol production distillery plant, *100,000 cubic* meter of biogas is released which is utilized as an energy in boiler. A 150,000 liters ethanol production capacity plant operates using 3 MWh electricity generated through biogas and bagasse; the energy released by Biogas can well be visualized. Some sugar mills have managed to isolate CO_2 gas from the biogas, so as to use methane as pure energy gas. The CO_2 so isolated account for 65 – 70 tons and is marketed for use in beverages.

5. Utilization of sugarcane waste and sugarcane industry waste products

.During various operations of cane harvesting, sugar manufacture and alcohol production, we are left with some wastes material in the field like trash and substances in the factory like press mud and spent wash. These are of immense value if properly handled and utilized.

Trash:

Trash includes top portion of cane stalks including green and dry leaves removed during harvesting and cleaning canes. Depending upon the stage of cane maturity trash is 23 to 30 % of cane weight. It may be left as crop residue in cane field as organic fertilizer or used as feed stock for livestock. The other option is to collect the trash and bring into the factory for use as feed stock with bagasse to produce thermal energy for sugar factory. Cane trash, with moisture range of 20-30%, is a potential fuel with a calorific value of 3545-4375 K Cal/kg (Kurt Woytrik, 2006). The energy released is around one kWh/Kg of trash (Zafar, 2021).

For the purpose of thermal energy, cane trash in cane field is raked and packed as cubic bundles (compressed 1^3 ft. cubes) and brought to the factory for its burning along with bagasse. Depending upon cane varieties and crop growth condition, 10-12 tons of trash can be collected per hectare and this biomass used as a source of bio-power.

Fertilizer value of sugarcane wastes

Three main residues namely cane trash, filter cake and spent wash, are very important from view point of their organic matter and macro and micro nutrients.

i. Sugarcane trash

The sugarcane trash is composed of 69% organic matter, 0.42% N, 0.15% P, 0.57% K, 0.48% Ca, 0.12% Mg, besides micronutrients Zn, Fe, Mn (Srivastava et.al, 1992). Green cane trash blanket left in field is almost 10 tons per hectare (Romers *et.al.* 2007). On decomposition it adds to soil 5.3 Kg N, 1.1 Kg P_2O_5 and 5.8 Kg K_2O per ton of trash; thus shows an economy of 75 Kg N (Verma, 2002). Thus besides meeting organic matter requirements, trash substitutes for the use of one bag each of nitrogen and Potash fertilizers for the crop. Sugarcane trash recycle nutrients back into the soil and increase the yields of ratoon crop by 33 % (Mendoza, 1987; Calcino, 2000).

ii. Press mud:

Press mud or filter press cake is a spongy, amorphous dark brown material containing soluble and insoluble impurities in sugarcane juice. This includes sugar, fiber particles, wax, inorganic salts and soil particles. During juice boiling they get coagulated and are separated through filtration process. Press mud consist of 75-80 percent water, 0.9-1.5% sugar, 32% organic carbon and nutrients like N, P, K, Ca, Mg and sulphur and minor elements viz. Fe, Zn, Mn, Cu, B and Mol (Sarangi *etal*, 2008). The presence of organic matter with macro and micro elements make the press mud most valuable organic fertilizer.

On a simple treatment with certain nitrogen fixing and phosphorus solubilizing microorganism like Azotobecter, Aspergilus, Trichoderma and decaying fungi it is converted to bio-compost and its nutritional value increases manifold. The press mud treated with spent wash make it highly nutritive and especially it gets enriched in Potash contents. Comparative nutritional values of sugarcane trash, farmyard manure, press mud and bio-compost are given in **Table-4.**

Table-4: Chemical composition of different organic manures *

Particulars	FYM	Cane trash	Press mud	Bio-compost
pH	6.5 - 7.5	6.55	7.18	7 - 8
Organic carbon	8 - 12	36.55	32.60	20 - 28
N %	0.3 - 0.5	0.44	1.2	2 - 2.5
P2O5 %	0.05 - 0.09	0.19	1.15	1.6 - 1.8
K2O %	0.4 - 0.6	0.46	0.62	4.05 - 6.0
Ca %	0.5 - 1.1	0.24	6.14	4.3 - 5.0

*Sarangi *etal* (2008)

Application of press mud improves soil structure and texture, enhances water holding capacity of soil, and brings soil nutrients in much available form to the plant. Ratoon yields are much improved. Press mud (70% moisture) @ 1.2% N, 1.15% P and 0.62% K adds to soil 3.6 Kg N, 3.45 Kg P and 1.26 Kg K per ton of the mud, while bio-compost (30% moisture) at the rate of 2

% N, 1.6 P % and 4 % K adds 14 Kg N, 11.2 Kg P and 28 Kg K per ton of bio-post. Use of compost for crop, on an average, results in saving of at least 1.5 bag each of N and P fertilizers and meets full needs of K application. It saves the cost of thousands of N, P, and K fertilizer bags.

Quantity available for Distribution to growers:

A 12,000 TCD capacity mills working for 120 days, is likely to produce 43,200 tons press mud in a season. Press mud at the rate of 20 tons per hectare would cover 2160 hectares in a season, while bio-compost at the rate of 10 tons per hectare would cover 4320 hectares. In this pattern may save the use of about 10,000 bags each of N, P and K fertilizers by the use of bio-compost.

iii. **Distillery effluent/spent wash/vinasse/stillage:**

During ethylene formation process, spent wash is left as residue @ 10-15 liter, for every one liter of alcohol produced. If spent wash is not properly treated it is extremely toxic to environments due to exorbitant gases discharge and highly concentrated salts. Its disposal becomes a problem for the mills management. And, on the other hand when properly treated it becomes environment friendly to use as organic fertilizer.

It helps reclaim soil salinity and with addition of organic matter improve physical structure of soil. Pre-sowing application of undiluted effluent @ 150 cubic meter (150,000 liters)/ha in soil or mixed with irrigation water @ 25 % at tillering stage increased yield of cane and saved fertilizer by N 50 kg/ha, P2O5 60 kg/ha and K2O 40 kg/ha (Srivastava *etal*, 2012). Spent wash application at tillering @ 25% also showed marked improvement in sugar recovery (Singh *etal*, 2007).

In a 12,000 TCD crushing plant, 15.228 million liters of alcohol was reported to be produced. During alcohol production 183 million liters of spent wash is likely to be produced at @ 12 liters per liter of alcohol. Spent wash application in soil @ 150,000 liters per hectare, would cover 1220 hectares in one season.

Besides soil amendment Spent wash application help save one bag each of Urea, DAP and Potash fertilizer. It is especially rich in ‘K’ contents and when applied meets full needs of crop for potash fertilizer.

In countries like Brazil, China Spent wash is liberally used as field application at pre-planting phase or as fertigation during tillering stage have helped to control the environmental pollution. In Pakistan, agricultural use of distillery effluent is entirely ignored and most of the factories are facing serious environmental pollution problems.

Annexture-1

Cogeneration proposal for a 12,000 TCD Plant

Summary		
S. No.	Description	With electric drive
1	Crushing Capacity (TPH)	500
2	Export During Season (kW)	31098
3	Season operating Days	120

4	Export During Off Season (kW)	23747
5	Off Season Operation days	104

Sugar plant operating data for a 12,000 TCD Plant		
S. No.	Description	With electric drive
1	Crushing capacity(TPH), Note-1	500
2	Bagasse produced(TPH) @ 30% on cane	150
3	Bagasse for bagacillo and losses	3.50
4	Bagasse available for usage in cogeneration(TPH)	146.51
5	2.5 bar (a) steam required @ 40%	200
6	Recoverable condensate-from 2.5 bar(a) steam to process	
7	4 bar(a) steam required for sugar process (TPH) Note-2	6.0
8	Condensate return from 4 bar steam supply	0.0
9	Electric power requirement of sugar mill (KW) @ 23 KWh per ton	11500
10	Average No. of sugar mill operating days	120
11	Total bagasse generation per season (MT)	
11.1	During the initial crushing days (10 days at a capacity utilization of 70 %)	24612
11.2	During steady crushing days (80 days of a capacity utilization of 90 %)	284796
11.3	During concluding crushing days (20 days at a capacity utilization of 60%)	42192
12	Total annual bagasse power generation	351600

II Season Operation **II.1: High Pressure Cogeneration System (Condensing Extraction Turbine)**		
S. No.	Description	
1	Boiler Outlet Steam Pressure (bar(a))	110
2	Boiler Outlet Steam Temperature (Deg.C)	540
3	Boiler Feed Water inlet Temperature (Deg.C)	210
4	No. of Boilers	1
5	Total Boiler Steam Generation capacity (TPH)	135
6	Individual Boiler Capacities (TPH/TPH)	135
7	Actual HP Steam Generation in Seaosn (TPH)	135
8	Bagasse consumption (TPH)	51.88
9	Extraction Condensing TG Capacity (MW)	26.50
10	Number of Extraction Condensing TGs	1
11	Generation in Condensing Extraction TG in season per hour (KW)	26340
12	Total Gross Power Generation in the HP System in Season (kW)	26340
13	2.5 bar(a) Process steam supply from HP Cogen Plant (TPH)	90
14	4 bar(a) steam supply to process from HP System (TPH)	0.00
15	HP Cogen Auxiliary Power Consumption (kW)	2371

II Season Operation

II.2: High Pressure Cogeneration System (Back Pressure Turbine)		
S. No.	Description	With electric drive
1	Boiler Outlet Steam Pressure (bar(a))	110
2	Boiler Outlet Steam Temperature (Deg. C)	540
3	Boiler Feed Water inlet Temperature (Deg. C)	210
4	No. of Boilers	1
5	Total Boiler Steam Generation capacity (TPH)	135
6	Individual Boiler Capacities (TPH/TPH)	135
7	Actual HP Steam Generation in Season (TPH)	135
8	Bagasse consumption (TPH)	51.88
9	Extraction back pressure TG Capacity (MW)	21
10	Number of Extraction Condensing TGs	1
11	Backpressure TG Capacity (MW)	21
12	Number of Backpressure TGs	NA
13	Generation in back pressure TGs in Season (kW)	21,000
14	Total Gross Power Generation in the HP System in Season (kW)	47340
15	2.5 bar(a) Process steam supply from HP Cogen Plant (TPH)	110
16	4 bar(a) steam supply to process from HP System (TPH)	0.00
17	HP Cogen Auxiliary Power consumption per hour (kW)	2371

III : Power Generation, Auxiliary Consumption & Export In Season		
S. No.	Description	
1	Generation in the HP system (Condensing Extraction Turbine)(kW)	26340
2	Generation in the HP System (Back Pressure Turbine) (kW)	21000
3	Total Power Generation in the Mill complex (kW)	47340
4	Auxiliary Power Consumption of HP system(Condensing extraction turbine) KWh	2371
5	Auxiliary power consumption of HP system(Back pressure turbine) (kWh)	2371
5	Power Consumption of the Sugar Mill (kW)	11500
6	Export from the Mill (kW)	31098

IV : Bagasse balances		
1	Bagasse from Crushing Operations (MT)	351600
2	Bagasse Consumption in the HP System	
	During the initial Crushing Days (MT)	8715.24
	During the steady crushing days	100854.72
	During the Concluding Crushing days (MT)	14940.42
	Total Seasonal Consumption in the HP system with Condensing Extraction Turbine(MT)	124510.38

	Total Seasonal Consumption in the HP system with Back Pressure Turbine(MT)	12451038
3	Total Bagasse Consumption in Season (MT)	249020.76
4	4 Saving in bagasse For Off-Season Operation (TPH) (Note 10)	102579.24
	Total Equivalent Bagasse Available for Off-Season Operation (MT)	102579.24

V : Off-Season Operation (Operation of the HP System with saved bagasse)		
S. N0.	Description	
1	1. Number of Boilers in Operation (Extracting Condensing Turbine)	1
2	Number of TGs in Operation	1
3	3. Total Steam generation (TPH)	106
4	4. Bagasse consumption (TPH)	41
5	Number of days of operation with saved bagasse (Note 11)	104
9	Gross power generation (kW)	26500
10	Power consumption in sugar plant (kW)	500
11	Auxiliary power consumption (kW)	2252.50
12	Exportable Power in Off-season (kW)	23747.50

VI : Annual Export		
S. N0.	Description	
1	Season Electrical Energy Export (Million Units) Considering plant Capacity Utilization factor s as discussed under note 1	89.56
2	Offseason Electrical Energy Export (With 97% CUF) (million Units) With Bagasse as the Fuel (Million Units)	59.27
3	Total Annual Electrical Energy Export (Million Units)	148.83

VII : Efficiency, Heat Rate & Specific Fuel Consumption of the HP Cogen plant (Note 12)		
S. No.	Description	
1	Bagasse Gross Calorific Value (kJ/kg)	9312.00
2	NCV of Bagasse (kJ/kg)	7456.23
3	Boiler Efficiency on GCV (%)	71.50
4	Boiler Outlet Steam Enthalpy (kJ/kg)	3459.40
5	Boiler Feed Water Enthalpy in Season (kJ/kg)	900.90
6	Boiler Duty in Season (MMkJ/hr)	345.40
7	Fuel Consumption in Season (TPH)	51.88

8	Net Heat Input to the Plant (MMkJ/hr)	386.80
9	Net Power Output in Season (kW)	23969.00
10	Net Heat Rate in Season (based on NCV) (kJ/kwhr)	16137.62
11	Net Plant Efficiency based on NCV in Season (%) (Note 13)	22.31

VIII. An Estimate of Bagasse Based Energy Potential of Pakistan Sugar Industry		
S.No.	Description	
1	Total crushing of all the sugar mills in Pakistan (Metric tons)	79,954,711
2	Total bagasse production {Metric tons)	23,986,13
3	Potential of electric export for 120 operating days (MWH)	2121.5
4	Potential of electric export during off season-104 days (MWH)	1620
5	Annual potential electric export-Billion kWh	10.15
6	Expected income @ Rs. 12/kWh- Billion Rs.	122

Conclusion

In agriculture sector sugarcane has its importance as a cash crop for growers and as sugar crop in food sector. It may be emphasized that there is also need to recognize its importance as an energy crop; as whole plant parts, the cane stalks, tops, green and dry leaves are resources of energy. The bagasse from sugarcane biomass produces steam energy which is utilized to run the factory and generate electricity to meet power needs of the sugar mills. While cane juice produce sugar and molasses and molasses becomes the resource for bio-ethanol as well as biogas.

With high pressure boilers and better processing efficiency, bagasse energy has a great potential to generate surplus electricity for supply to the national Grid. With present day cane crushing capacities (79.954 million tons) of sugar industry, Pakistan has the potential to generate 2500 MWh electricity in a crop season.

During current crop season (2021-22), Pakistan produced 3.598 million tons of molasses. Based on 70 percent utilization of molasses in distilleries, as much as 591.87 million liters of ethanol can be produced which if converted to biofuel can replace 3.946 liters of gasoline.

During cane clarification and ethanol distillation waste products are separated as press mud and spent wash which can be utilized as organic fertilizer. This source has the capacity to substitute more or less 10,000 bags each of N, P, K fertilizers, along with addition of organic matter in soil.

These data information should be eye openers for Govt. planners and sugar mills administration to frame policies to utilize the energy potential of the sugarcane in best interest of the country.

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