Thermal Power Generation Through Biomass Energy Source

Prepared By

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Biomass Energy Economics

Scope of Discussion

Large Industrial and Utility Energy Facilities

- **Industrial Steam System (100,000 lb/hr & greater)**
- **Thermal Electric Power (10 to 50 MW)**
- **Combined Heat & Power (5 to 50 MW)**

Biomass Energy Sources

Rice Husk, Wheat Straw, Wood And Wood Waste, Sugarcane Bagasse & Trash

Plant Configuration & Allied Facilities (10 to 50 MW)

• Biomass Storage/Processing Units, Gasification Plant

• Water Treatment Plant/Storage Tanks, Cooling Tower

• Hi-Pressure Boilers, Steam Turbines & Control System

Inroduction:

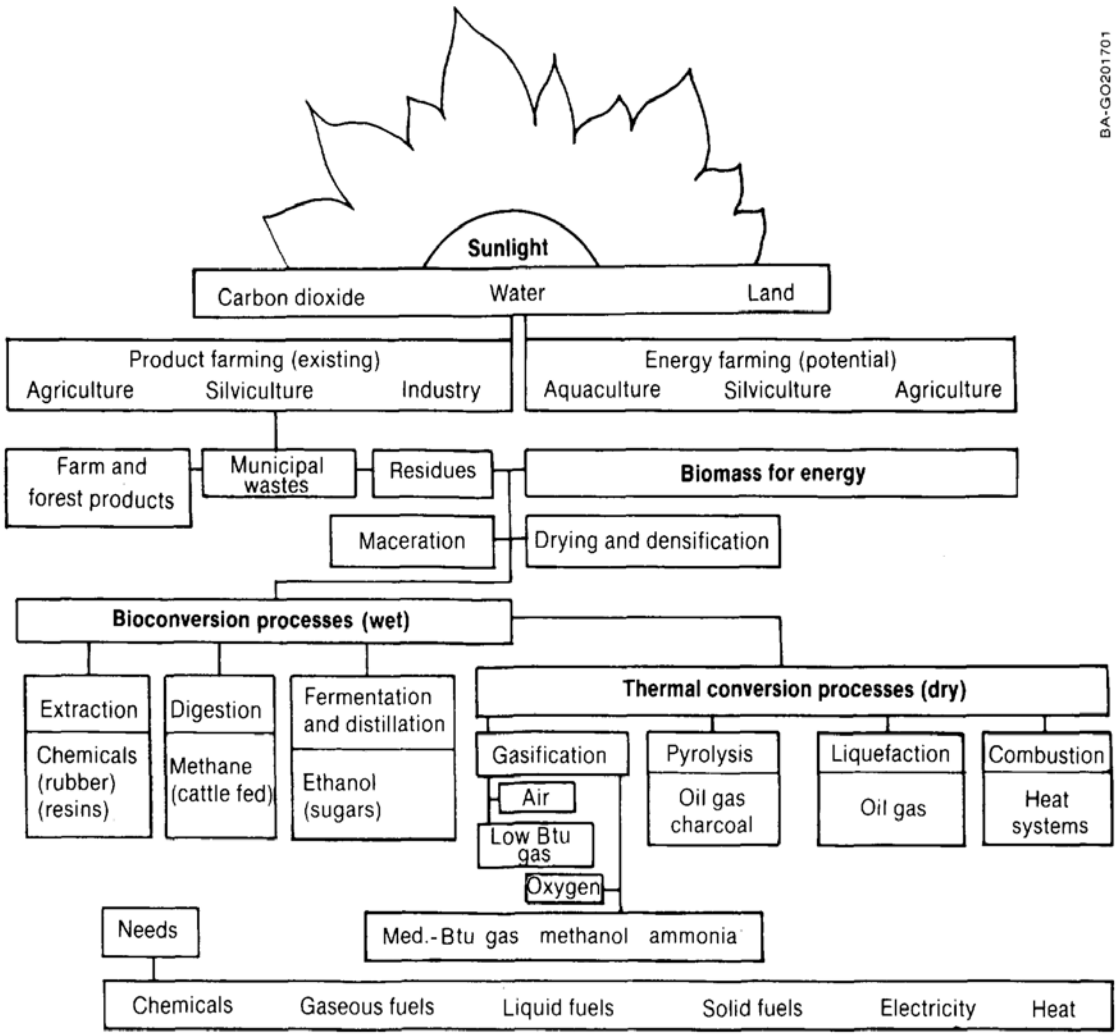
The use of biomass as a fuel is not a new concept but it is in use since many century in different shapes. Well time have changed, and with the high and high cost of fossil fuel and shortage of power, not just individual consumers but even industries are hard pressed to find ways to utilize their waste biomass in productive Ways.

Conversion of biomass to syn. Gas which can then be either burnt to drive turbines, or converted via fischer-tropsh type reaction in to value added chemical and fuels, has recently gained a lot of attention world wide.

Biomass resources fall in to two categories;

1: Wet or wet table biomass (molasses, starches and manures)

2: Dry biomass (woody and agricultural material and residues)



Biomass Gasification:

1- Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engine (both compression and spark ignition)

2- Biomass gasification is an endothermic thermal conversion technology where a solid fuel is converted into a combustible gas. A limited supply of Oxygen, air, steam or a combination serves as the oxidizing agent. The product gas consists of carbon monoxide, carbon dioxide, hydrogen, methane, trace amounts of higher hydrocarbons (ethane, ethane), water, nitrogen (with air as oxidant) and various contaminants, such as small char particles, ash, tars, higher hydrocarbons etc.

Theory of Gasification:

The production of generator gas (producer gas) called gasification, is partial combustion of solid fuel (biomass) and takes place at temperature of about 1000ºC. The reactor is called gasifier

. The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion) the products of combustion are (Figure 1) combustible gases like Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane and nonuseful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal. Thus the key to gasifier design is to create conditions such that a) biomass is reduced to charcoal and, b) charcoal is converted at suitable temperature to produce CO and H_2.

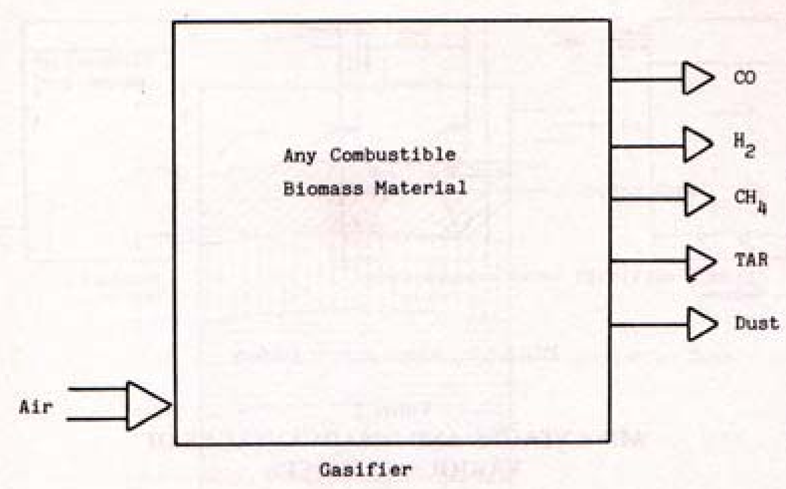


FIGURE 1. Products of gasification.

Types of Gasifier:

Since there is an interaction of air or oxygen and biomass in the gasifier, they are classified according to the way air or oxygen is introduced in it. There are three types of gasifiers Downdraft, Updraft and Crossdraft. And as the classification implies updraft gasifier has air passing through the biomass from bottom and the combustible gases come out from the top of the gasifier. Similarly in the downdraft gasifier the air is passed from the tuyers in the downdraft direction.

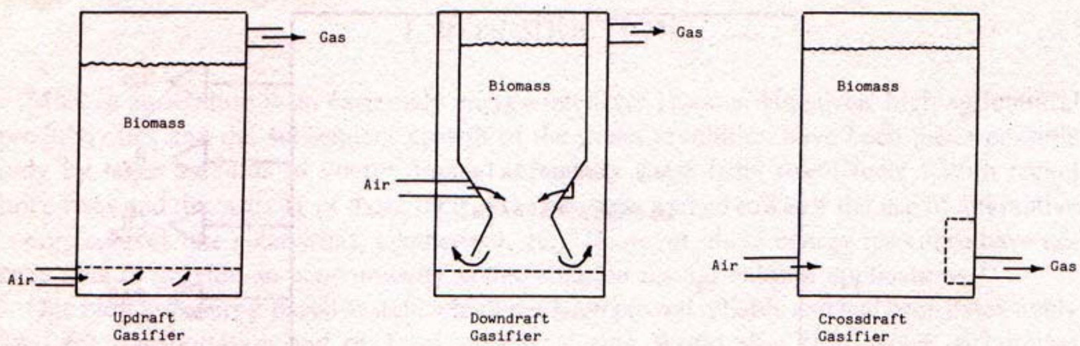


FIGURE 2. Various types of gasifiers.

Sr. No.	Gasifier Type	Advantage	Disadvantages
1.	Up draft	- Small pressure drop - good thermal efficiency little tendency towards slag formation	Great sensitivity to tar and moisture and moisture content of fuel relatively long time required for start up of IC engine poor reaction capability with heavy gas load
2.	Down draft	Flexible adaptation of gas production to load low sensitivity to charcoal dust and tar content of fuel	- Design tends to be tall not feasible for very small particle size of fuel
3.	Cross draft	- Short design height very fast response time to load - flexible gas production	Very high sensitivity to slag formation - high pressure drop

PROCESS

Chemistry

The substance of a solid fuel is usually composed of the elements carbon, hydrogen and oxygen. In the gasifiers considered, the biomass is heated by combustion. Four different processes can be distinguished in gasification: drying, pyrolysis, oxidation and reduction. From a chemical point of view, the process of biomass gasification is quite complex. It includes a number of steps like

- thermal decomposition to non-condensable gas, vapors and char (pyrolysis);
- subsequent thermal cracking of vapors to gas and char;
- gasification of char by steam or carbon dioxide;
- partial oxidation of combustible gas, vapors and char.

Reactions

In complete combustion, carbon dioxide is obtained from the carbon and water from the hydrogen. Oxygen from the fuel will be of course incorporated in the combustion products, thereby decreasing the amount of combustion air needed.

Combustion, occurring in the oxidation zone, is described by the following chemical formulae:

$C + 0_2 = C0_2 + 401.9$ kJ/mol (1)

$H + ½0_2 = H_20 + 241.1$ kJ/mol (2)

The most important reactions that take place in the reduction zone of a gasifier between the different gaseous and solid reactants are:

$C + C0_2 + 164.9$ kJ/mol $= 2C0$ (3)

$C + H_20 + 122.6$ kJ/mol $= CO + H_2$ (4)

$C0_2 + H_2 + 42.3$ kJ/mol $= CO + H_20$ (5)

$C + 2H_2 = CH_4$ (6)

$CO + 3H_2 = CH4 + H_20 + 205.9$ kJ/mol (7)

Properties of Producer gas

The producer gas is affected by various processes as outlined above hence one can expect variations in the gas produced from various biomass sources. Table 2 lists the composition of gas produced from various sources. The gas composition is also a function of gasifier design and thus, the same fuel may give different calorific value as when used in two different gasifiers. Approximate values of gas from different fuels.

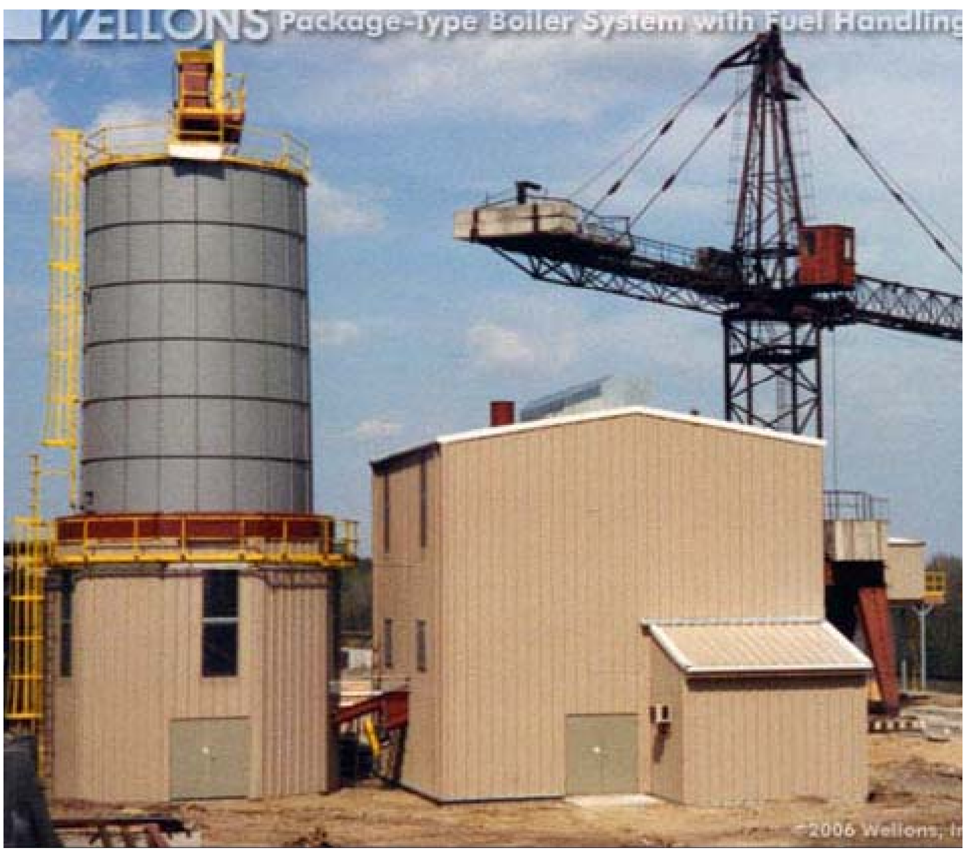
-Composition of Producer Gas from various fuels

Fuel	Gasification Method		Volume	Percentage			Calorific value Mj/m³	Ref.
		CO	H_2	CH_4	CO_2	N_2		
Charcoal	Downdraft	28-31	5-10	1-2	1-2	55-60	4.60-5.65	12
Wood with 12-20% moisture content	Downdraft	17-22	16-20	2-3	10-15	55-50	5.00-5.85	12
Wheat straw pellets	Downdraft	14-17	17-19	-	11-14	-	4.50	15
Coconut husks	Downdraft	16-20	17-19.5	-	10-15	-	5.80	15
Coconut shells	Downdraft	19-24	10-15	-	11-15	-	7.20	15
Pressed Sugarcane	Downdraft	15-18	15-18	-	12-14	-	5.30	15
Charcoal	Updraft	30	19.7	-	3.6	46	5.98	16
Corn cobs	Downdraft	18.6	16.5	6.4	-	-	6.29	17

Rice hulls pelleted	Downdraft	16.1	9.6	0.95	-	-	3.25	17
Cotton stalks cubed	Downdraft	15.7	11.7	3.4	-	-	4.32	17

Characteristics of Biomass Steam Systems

- **Capital - $5 to $15 Million**
- **Fuel for 50,000lb/hr avg. - 65,000 green tons/yr**
- **Efficiency - 70%+**
- **Jobs - Fuel supply**
- **Economic Development - local industry**
- **System Economy through Renewable Fuel Source**
- **Global Warming - Positive impact, if sustainable**
- **Significant space for fuel storage and equipment**
- **Additional operating staff compared to gas/oil**
- **Non-fuel O&M Costs greater than gas/oil fuels**



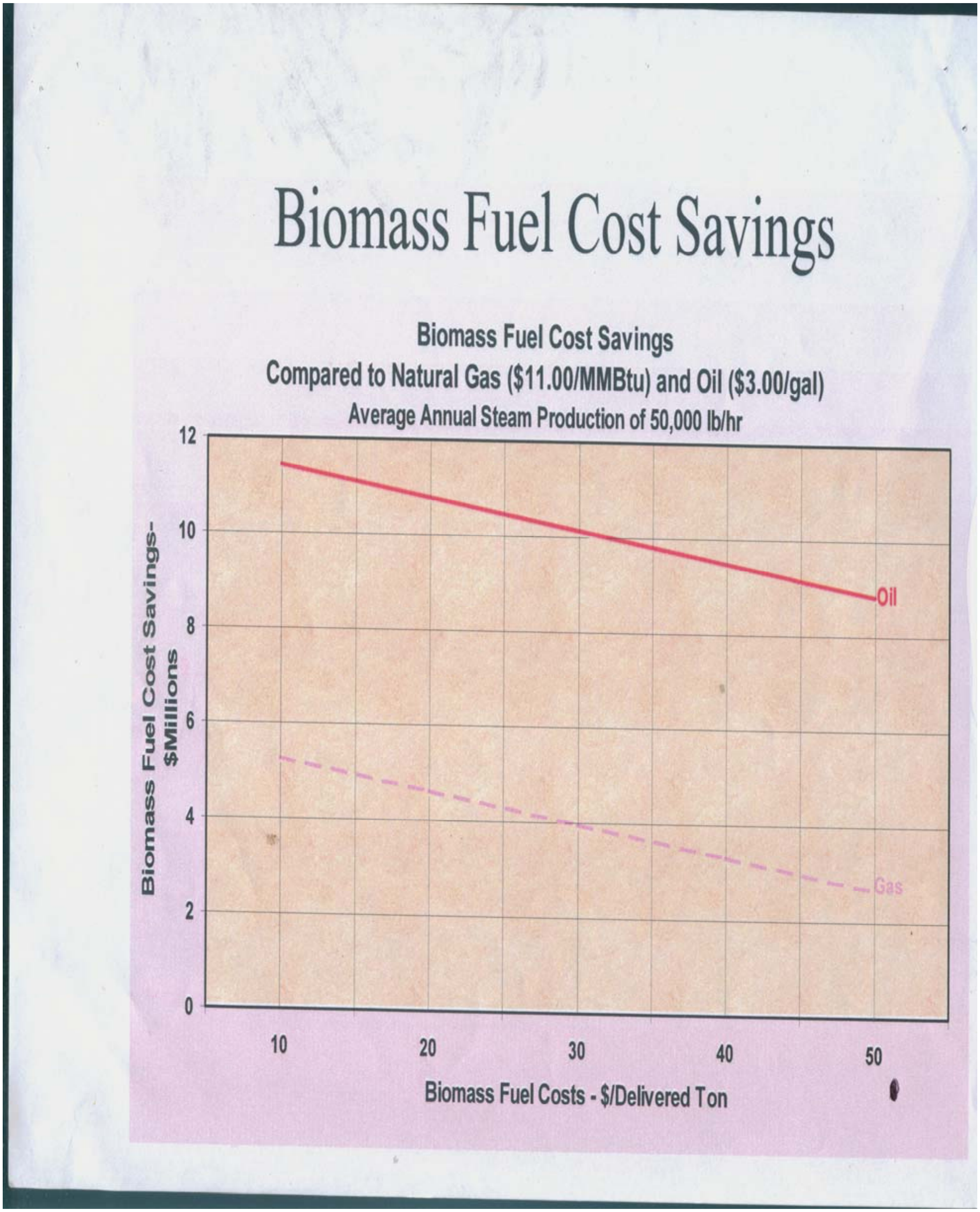
Comparison of Steam Fuel Cost[a]

Factor	Natural Gas	Biomass (b)	Oil
Assumed Fuel Cost	$ 11.00per MMBtu	$20.00 per Ton ©	$ 3.00 per Gallon
Fuel Cost per MMBtu	$ 11.00	$ 2.14 (b)	$ 19.23
Assumed Boiler Efficiency	82.0%	72.0%	84.0%
Fuel Cost per 1,000 lb of steam	$ 13.41	$ 2.98	$ 22.89
Annual Cost-50,000 lb/hr	$5,875,610	$1,303,200	$12,729,768
Annual Biomass Fuel Saving-50,000 lb/hr Average	$ 4,572,410	Base	$ 10,729,768

a- **Assume steam condition 150 psia, saturated, and 1,000 Btu/lb of steam produced.**

b- **Based on 45% moisture and higher heating value of 4,688 Btu/lb wet.**

c- **Wood cost delivered at 45-percent moisture.**


Biomass Fuel Cost Savings
Biomass Fuel Cost Savings
Compared to Natural Gas ($11.00/MMBtu) and Oil ($3.00/gal)
Average Annual Steam Production of 50,000 lb/hr
Biomass Fuel Cost Savings- $Millions
0
2
4
6
8
10
12
Oil
Gas
10
20
30
40
50
Biomass Fuel Costs - $/Delivered Ton

Thermal-Electric Power Production

- Fuel required for 40 MW
- About 527,000 green tons/yr
- Efficiency – 70%
- Construction jobs – 40 to 80
- Construct duration – 18 months.
- Jobs for plant operation – 21
- Jobs for fuel production – numerous
- Incentives–Economical Bio Fuel Usage
- Carbon Tax Credits
- Global Warming- Positive, if sustainable
- Requires about 20 acres minimum

-Biomass Power Plant Characteristics

- Minimum Plant Size – 10 MW
- Maximum Plant Size – 50 MW
- Strong Economy of Scale Favors Larger Plants

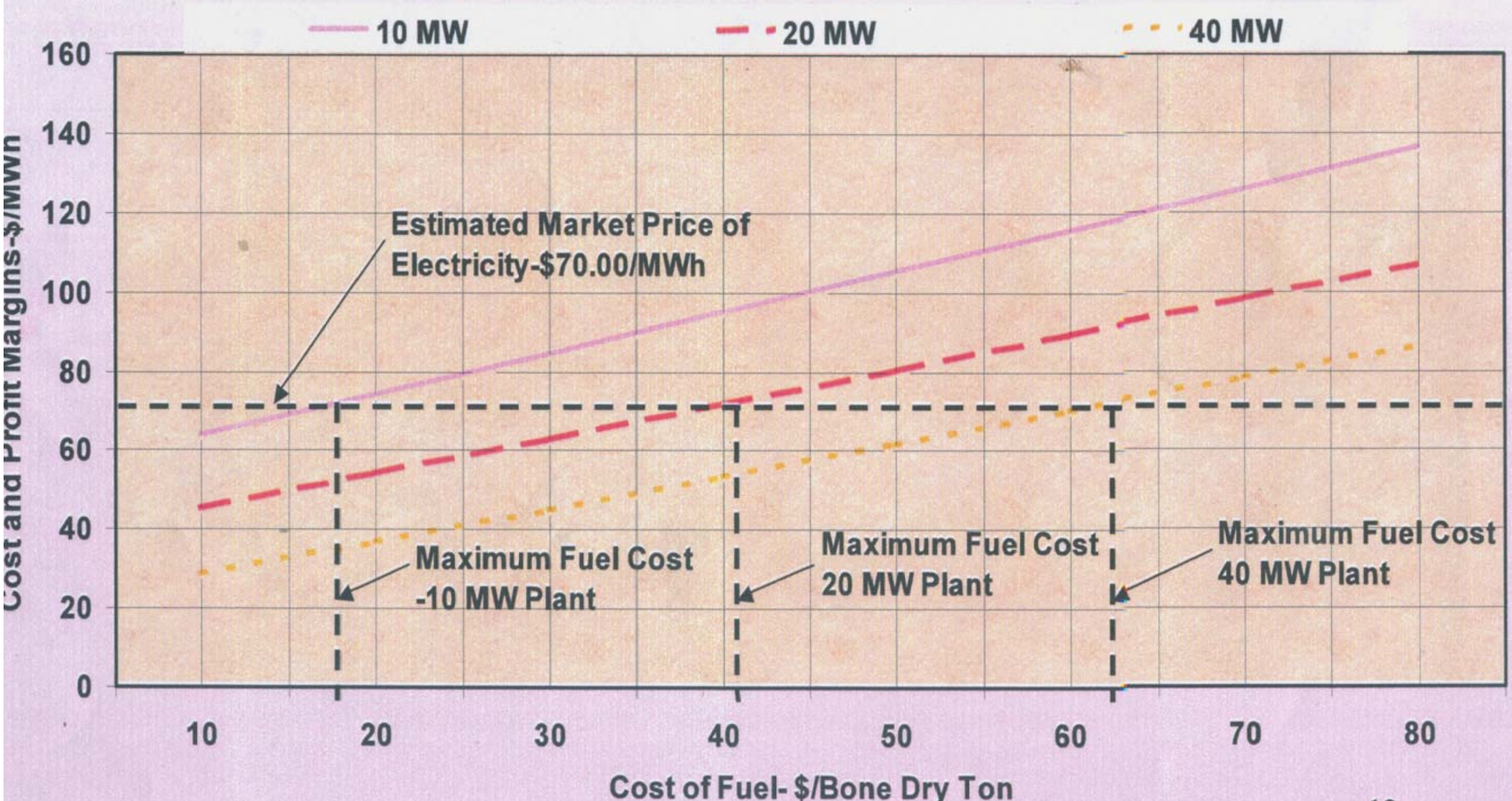
-Capital Cost
-Operation & Maintenance Staffing Cost
-Performance (More Efficient)

-Biomass Power Plant Fuel Requirement

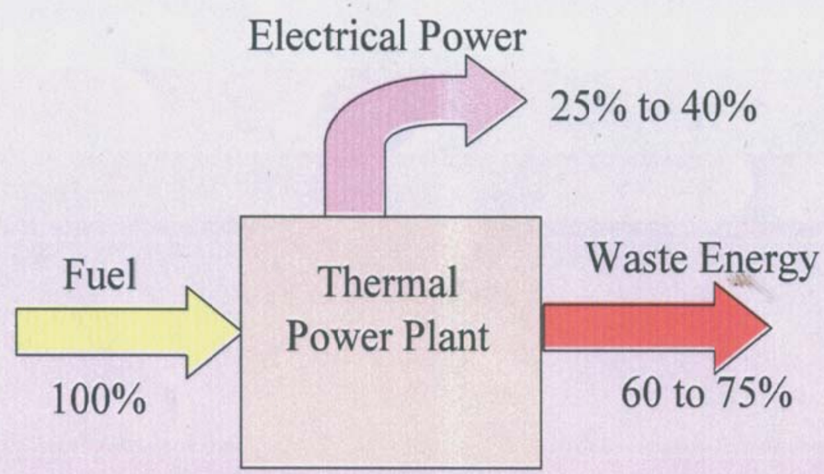
Plant Capacity	Heat Rate Tons/MWh[a]	Annual Fuel Tons (b)
10	2.0	165,000
20	1.70	280,000
40	1.60	527,000

a. Based on fuel moisture of 45% and a higher heating value of 8,400 Btu/lb dry.
b. Based on the design output, heat rate, and an annual capacity factor of 94%.

Fuel Cost, O&M Cost, and Profit Margins Biomass Power Generation-$/MWh



Typical Thermal Power Plant Efficiencies



	Heat Rate	Electrical Efficiency
Natural gas combined-cycle	7,500 Btu/kWh	45.5%
Coal-fired steam-electric	10,000 Btu/kWh	34.1%
Biomass-fired steam-electric	15,000 Btu/kWh	22.7%

-Combined Heat & Power Production

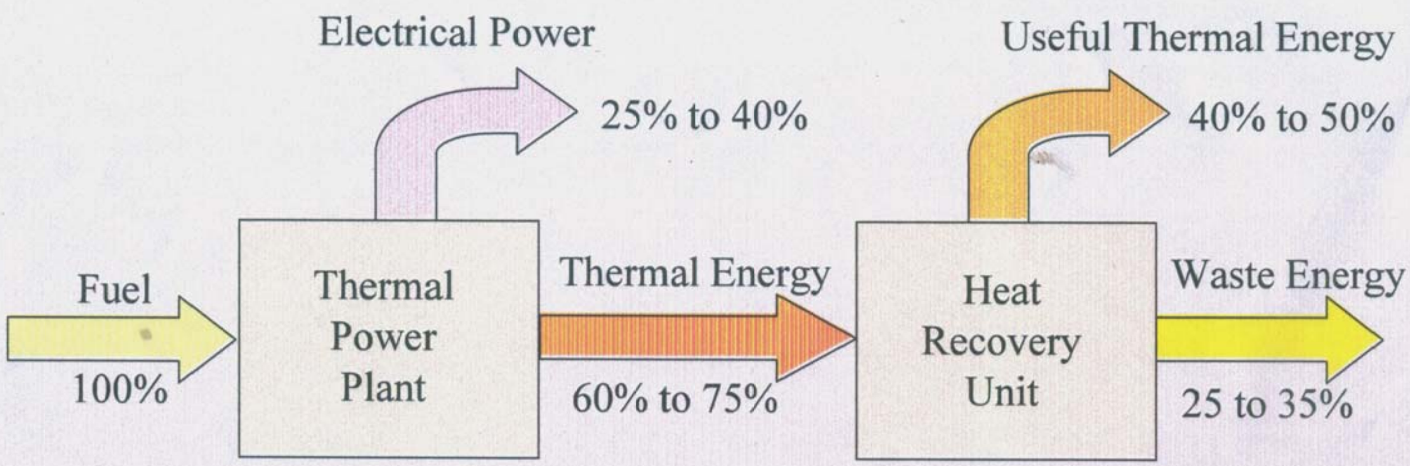
- **Fuel for 200,000 lb/hr steam & 50MW about 650,000 ton/yr @ 45% Moisture.**
- **Efficiency – 70%**
- **Construction jobs – 40 to 80**
- **Construct duration – 18 months**
- **Jobs for plant operation – 25**
- **Jobs for fuel production - numerous**
- **Incentives –Economical Bio-Fuel**
- **Carbon Credits**
- **Global Warming- Positive-if sustainable**
- **Requires between 20 and 25 acres**

-Biomass High Efficiency CHP Advantages

- **Lower Capital Cost**
- **Lower Operation & Maintenance Costs**
- **Higher Efficiency for Power Generation**

Annual Fuel -Tons	Steam Produced	Estimated Power
165,000	100,000 lb/hr	2,450 kw
280,000	200,000 lb/hr	5,700 kw
527,000	392,000 lb/hr	11,200 kw

Typical Power Plant Efficiencies

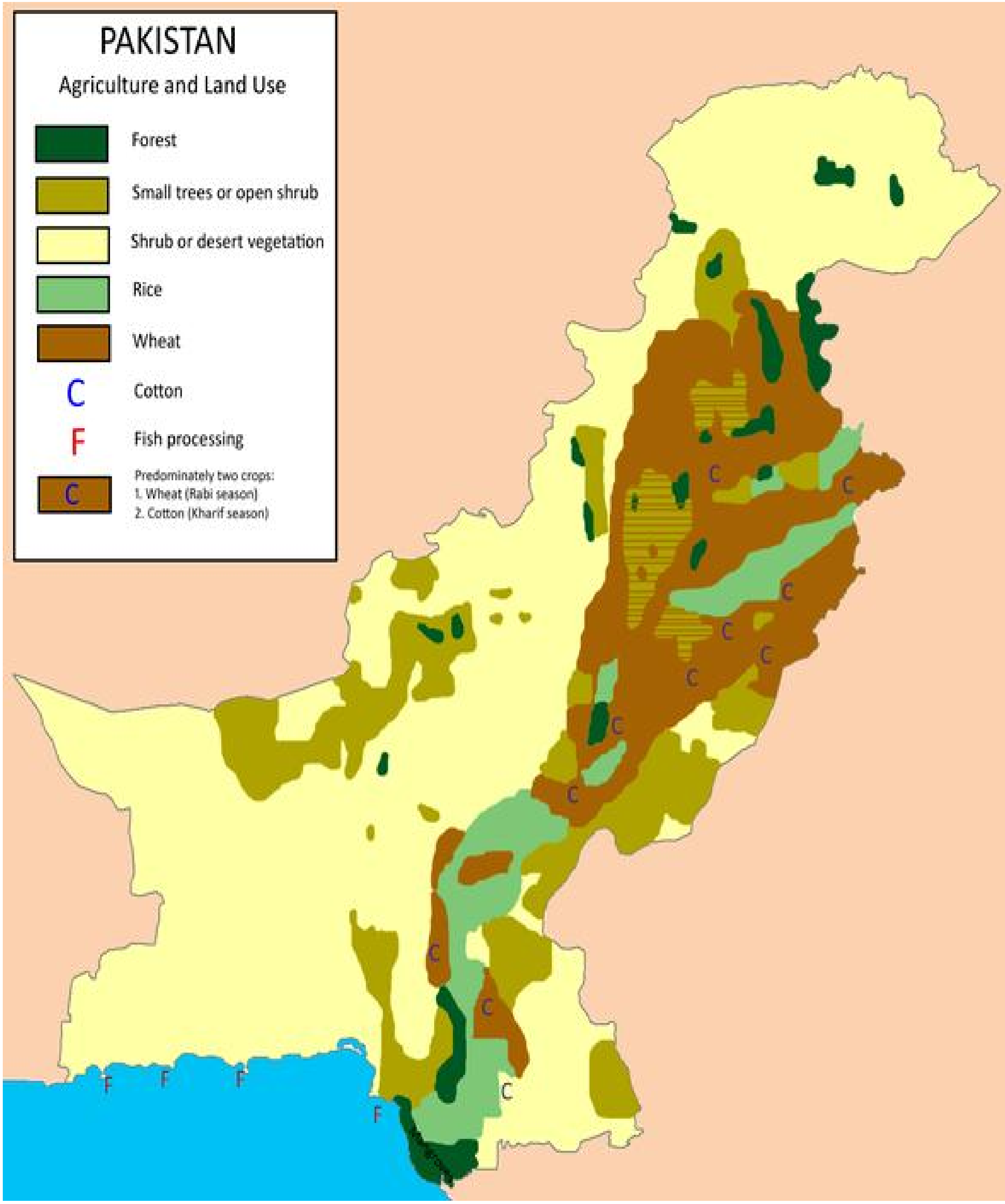


	Heat Rate	Electrical Efficiency	Overall Efficiency
Natural gas combined-cycle	7,500 Btu/kWh	45.5%	45.5%
Coal-fired steam-electric	10,000 Btu/kWh	34.1%	34.1%
Biomass-fired steam-electric	15,000 Btu/kWh	22.7%	22.7%
Biomass-fired CHP	8,500 Btu/kWh	40.1%	70.0% max

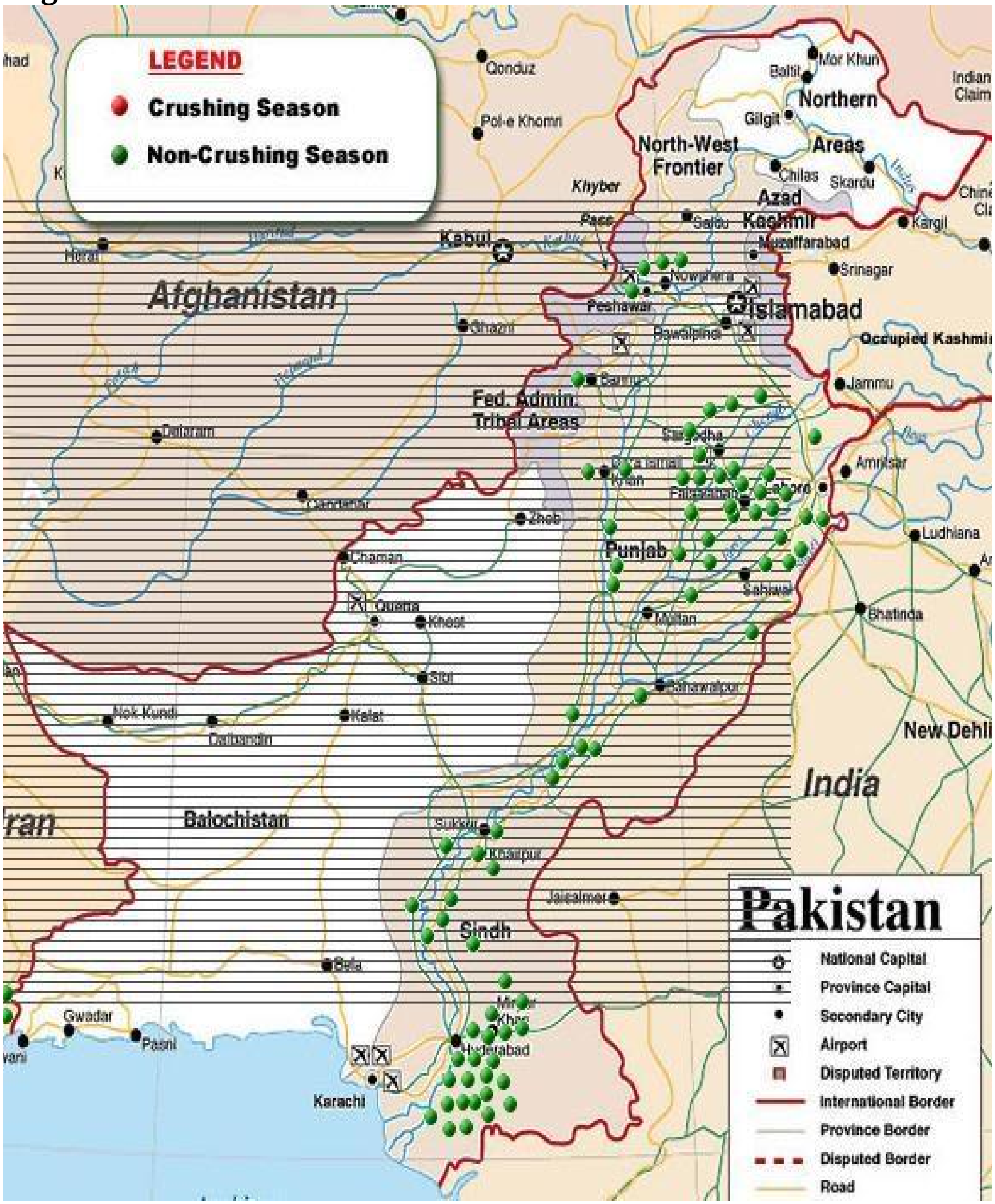
Scope of Biomass Power Generation in Pakistan

- **Rice Husk**

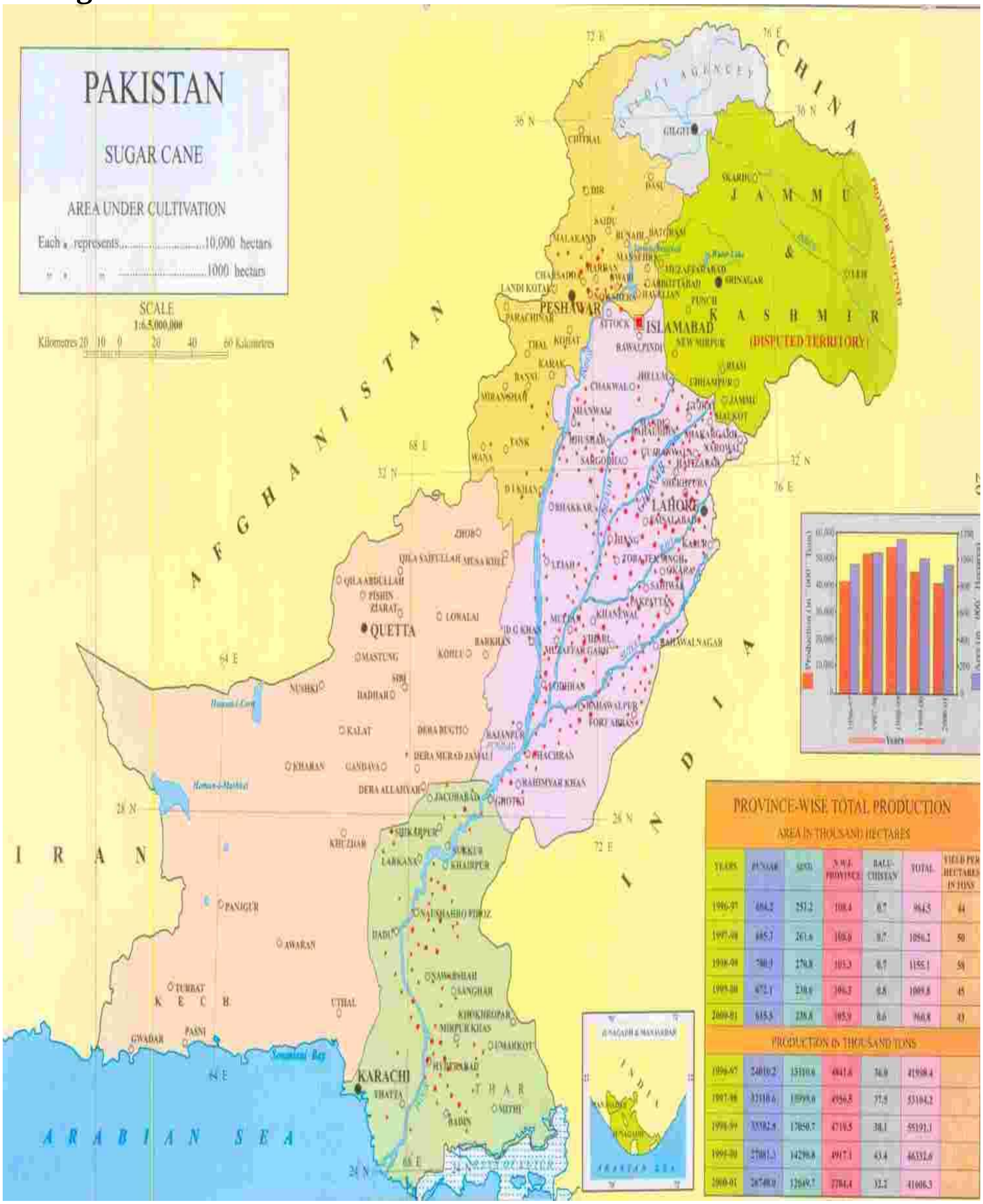
- **Wheat Straw**


PAKISTAN
Agriculture and Land Use
Forest
Small trees or open shrub
Shrub or desert vegetation
Rice
Wheat
Cotton
Fish processing
Predominately two crops:
1. Wheat (Rabi season)
2. Cotton (Kharif season)

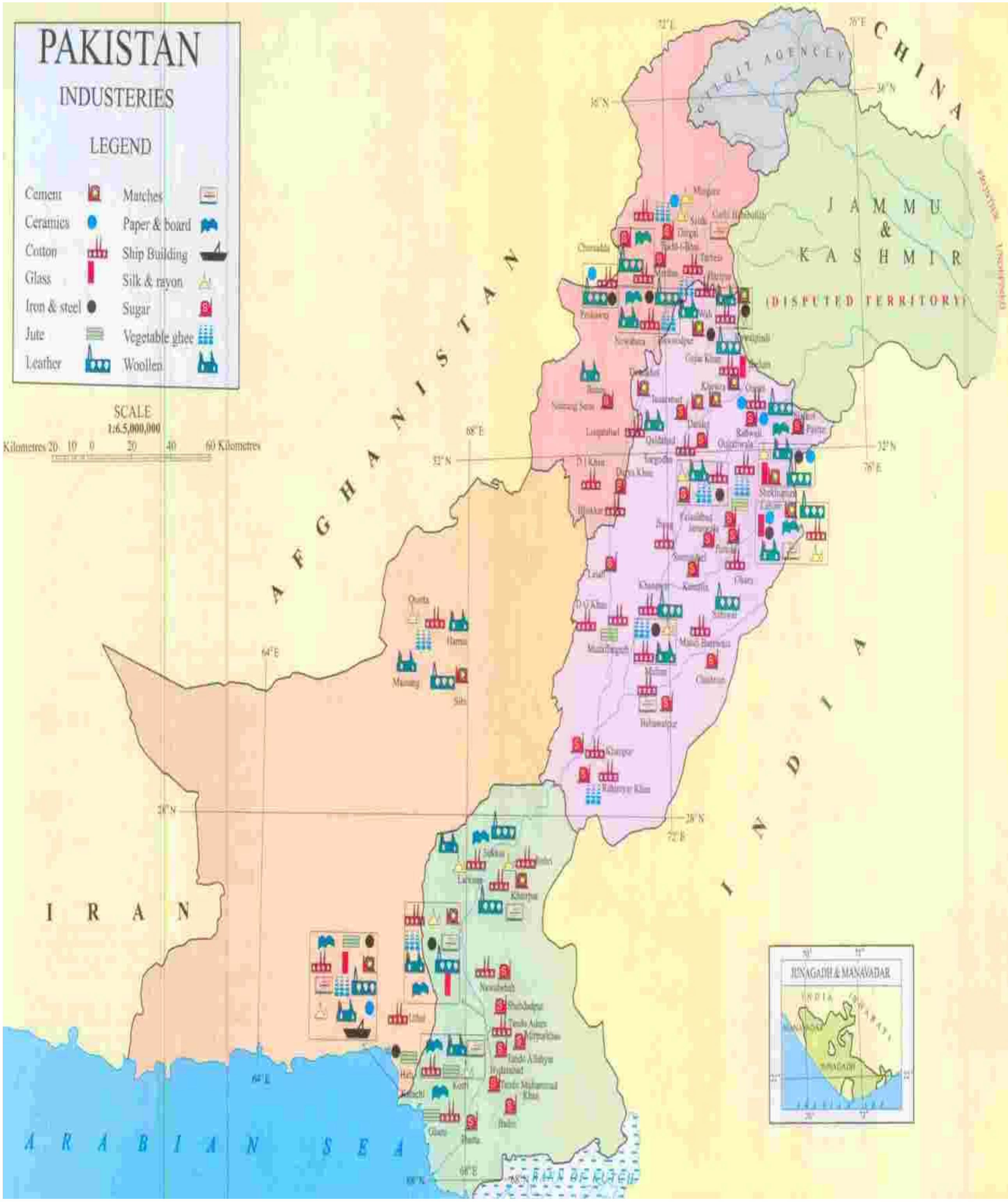
- **Sugarcane Mills**



- ## Sugarcane Cultivation Area



- **Pakistan Industries**



➢ Power Generation from Sugarcane Bagasse and Sugarcane Waste

In fact, power generation from sugarcane bagasse is very cheaper than other fuels i.e. fossil fuels. All the sugar mills meet their energy requirements from their own source obtaining bagasse from sugarcane after extraction of juice. Bagasse is fed directly to boilers to generate steam for heating and energy generation. The bagasse which is directly fed to boiler has moisture near to 45% to 50%, which mostly cause a slag and extra consumption of bagasse.

The other cause of extra bagasse usage is low pressure steam boilers which are maximum in operation in Pakistan.

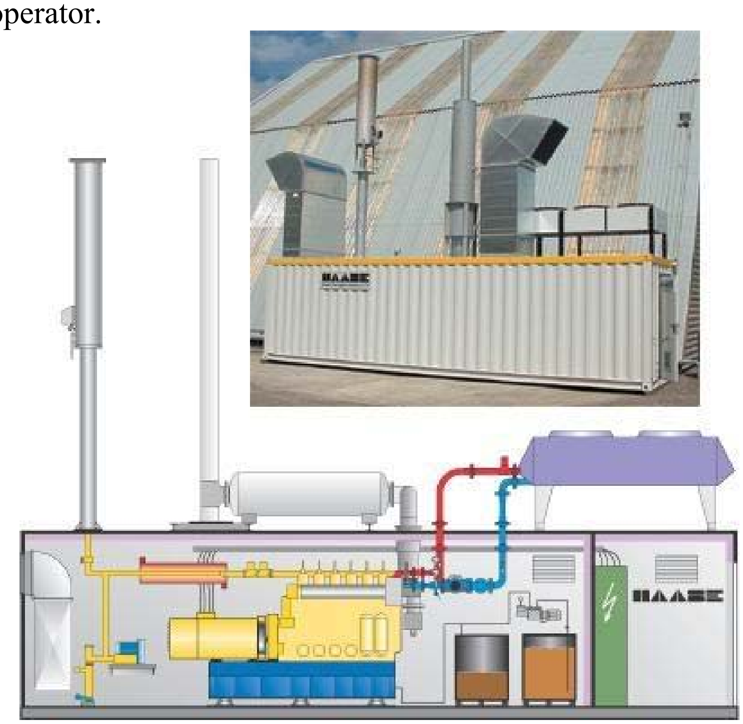
Mostly sugar mills only use bagasse during the running season and the very little quantity of bagasse, they save to start the coming season.

There is no any processing unit of bagasse in Pakistan to process the bagasse before feeding the boiler. If we process the bagasse and use of high pressure boiler, then we can save 20% to 30% more bagasse than direct feeding.

-The sugarcane trash is not in use in our industry. We totally waste it in the field and a very little quantity is used for cattle feeding in Pakistan. Now in other countries, they are going to start sugarcane trash as a fuel in boilers but they shall process before feeding the boiler. If the sulpher contents are higher in trash then first they shall process to decrease the sulpher contents and then they shall use in boilers.

Pakistan has now entered the field. The first sugarcane-waste bio-gas plant is now operating at the site of Shaker Gang Sugar Mills in Jhang and is producing 8MW of co-generated energy.

The bio gas used to fuel the plant is extracted from spent wash, which is a residual of the mills ethanol production operation that uses sugarcane molasses as a raw material. In addition to powering the mill, electricity from the plant is being delivered to the national grid through 22- years' power purchase agreement with the local grid operator.



➢ Power generation from rice husk &Wheat Straw

Pakistan is an agricultural country. There is a lot of scope for power generation from rice husk in Pakistan. See map on page 16. Cultivation of rice is in wide area in Pakistan and big exporter of rice.
There is no proper use of rice husk in Pakistan. Only it is used to small brick making industry which is waste of rice husk.
Rice husk can use for power generation but it will not use directly in the boilers.
A big power generation plant can install in rice and wheat area. In the province of Punjab, there is a big area or rice and wheat. Both rice husk and wheat straw shall use in power plant after processing.
Between Lahore, Shekhupura, Hafiz Abad, Gujranwala and Sialkot is the best area for power generation from rice husk and wheat straw.
Sugarcane bagasse can also used after processing with rice husk and wheat straw.
A huge quantity can be collected of bagasse and sugarcane trash from the Punjab area.
The system will run as,
Big storage area→ processing of sugarcane bagasse and trash, rice husk, wheat straw→ Gasification →feeding to boilers→steam generation→ power generation.

➢ Power generation from wood and wood waste

There is lot of shortage of wood in Pakistan. There is also shortage of forests to reduce the pollution. Only some forests are in mountain area which is in north of Pakistan and some in interior of Sind province. It in not feasible of power plant on wood and wood waste in Pakistan.
There is lot of big, huge forests in Brazil and they are generating power from wood and wood waste. They are cutting wood from forests and then making chips, pellets, briquette and using for power generation.
Power generation with import of wood and wood waste is very very expensive.

Conclusions

1. Biomass energy is an important economic resource.
2. High efficiency biomass CHP is very attractive from economic and energy efficiency prospective.
3. Neutral greenhouse gas if done sustainably.
4. Development of biomass energy system will depend on the robust and reliable biomass fuel supply- price depend on plant location & local resources.
5. Biomass energy systems are very capital intensive.
6. Biomass O&U is higher than other fuels.
7. Large incentives for collectors of fuels/feedstock.
8. Biomass gasification offers the most attractive alternative energy system for agriculture purpose.
9. Very limited experience has been gained in gasification of biomass residues.
10. Several economic studies have been made on biomass gasification regarding the feasibility and long-term prospects. The projects are mostly far too expensive to become profitable.
11. Another aspect is the operational costs, in particularly the price of the feedstock. Transportation, fuel handling and processing adds to the cost of the feedstock. Furthermore, labour cost must be minimized through process control and automation.
12. For the short term to medium term, biomass gasification can not compete with fossil fuel.
13. The biomass gasification can compete with other RES when capital cost can be reduced and favorable conditions are created.

Thank You!

Rana Munawar Rashid