A CRITICAL EVALUATION OF OPERATIONAL EFFICIENCY OF SUPPLY CHAIN MANAGEMENT OF BIOMASS AS FEED STOCK TO THE POWER PRODUCERS IN RAJASTHAN (WITH SPECIAL REFERENCE TO KOTA)

A Thesis

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In Business Administration

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To the

UNIVERSITY OF KOTA

By

Garima Jain

Under the Supervision of

Prof. Rajeev Jain

Department of Commerce and Management

UNIVERSITY OF KOTA, KOTA (RAJ.)

2020

CERTIFICATE

I feel great pleasure in certifying that the thesis entitled **"A CRITICAL EVALUATION OF OPERATIONAL EFFICIENCY OF SUPPLY CHAIN MANAGEMENT OF BIOMASS AS FEED STOCK TO THE POWER PRODUCERS IN RAJASTHAN (WITH SPECIAL REFERENCE TO KOTA)"** By **Garima Jain** under my guidance. She has completed the following requirements as per Ph.D. regulations of the University:

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(c) Regularly submitted annual progress report.

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Date: **Prof. Rajeev Jain**

Place: Kota (**Research Supervisor)**

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ABSTRACT

The present research is intended to study and evaluate the problems and challenges faced by the farmers, middlemen, and the employees who are the main stakeholders of the biomass supply chain. The primary aim of this research is to estimate the cost of procuring biomass feed stock and to analyze the loss of calorific value in various stages of supply chain (harvesting, storing, handling and transportation) so that power stations will get biomass fuel of right specification, in the right amount, at the right time from resources which are typically diverse and are seasonally dependent.

The study will give an insightful analysis of how to help the present and the upcoming power generating companies with regard to the type of mix (biomass and coal) they should use in the form of feedstock for the generation of power.

Biomass – the fourth largest energy source after coal, oil and natural gas is the most important renewable energy option at present and can be used to produce different forms of energy. As a result, together with the other renewable energy options, it is capable of giving all the energy services required in a present-day society, both locally and globally. The supply of sustainable energy is one of the main challenges that mankind will face over the coming decades. Biomass can make a substantial contribution in supplying future energy demand in a sustainable way as it is a versatile and renewable source. The present study shows that the use of biomass must be increased all around the world and the husk and waste of plants should be used efficiently to make the environment pollution and carbon free.

CANDIDATE'S DECLARATION

I hereby, certify that the work which is being presented in the thesis entitled **"A CRITICAL EVALUATION OF OPERATIONAL EFFICIENCY OF SUPPLY CHAIN MANAGEMENT OF BIOMASS AS FEED STOCK TO THE POWER PRODUCERS IN RAJASTHAN (WITH SPECIAL REFERENCE TO KOTA)"** for the partial fulfillment of the requirement for the award of the Degree of Doctor of Philosophy, carried out under the supervision of Prof. Rajeev Jain submitted to the Department of Commerce and Management, University of Kota, Kota represents my ideas in my own words and where other ideas or words have been included, I have adequately cited and referenced the original sources. The work presented in this thesis has not been submitted elsewhere for the award of any other degree or diploma from any institution.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will cause for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or from whom proper permission has not been taken as needed.

Date: **Garima Jain**

Place: Kota

This is to certify that the above statements made by Garima Jain (Registration No.RS/259/13) is correct to the best of my knowledge.

Date: **Prof. Rajeev Jain**

Place: (Research Supervisor)

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Garima Jain

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ABBREVIATIONS

BPG	Biomass Power Generation
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
EERE	Energy Efficiency and Renewable Energy
EJ	Exa Joule
GCV	Gross Calorific Value
GHG	Green House Gas
GW	Giga watt
GWh	Giga watt hour
HHV	High Heating Value
IISc	Indian Institute of Science
IPCC	Inter-governmental Panel on Climate Change
KT/Yr	Kilo Tons per year
LCA	Life Cycle Assessment
LHV	Lower Heating Value
MNRE	Ministry of New and Renewable Energy
MT/Yr	Metric tons per year
MW	Megawatt
RREC	Rajasthan Renewable Energy Corporation
SAR	Second Assessment Report
SCM	Supply Chain Management
SSCM	Sustainable Supply Chain Management
TGA	Thermo Gravimetric Analysis
WAB	Waste Agriculture Biomass

CHAPTER-1

An Overview of Biomass Power Generation and its Supply Chain Management

1.1 Introduction

Biomass is biological material derived from living, organisms. It most often refers to plants or plant-based materials which are specifically called ligno cellulosic biomass.

Biomass is defined as any organic matter that is available on a renewable or recurring basis. It comprises of all crop residues and materials derived from plants, which include agricultural crops and trees, wood and wood residues, grasses, aquatic plants, animal manure, municipal residues, and other left over materials.

It is derived from numerous sources, including the by-products from the wood industry, agricultural crops, major parts of household waste, raw material from the forest and wood.

Industrial biomass can be grown from numerous types of plants including miscanthus, switchgrass, hemp, corn, poplar, willow, sorgham, sugarcane, and a variety of tree species, ranging from Eucalyptus to oil palm (palm oil). The particular plant used is usually not important for the end results, but it does affect the processing of the raw material.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. One of the major advantages of biomass is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Biomass is an important source of energy and the most important fuel all over the world after coal, oil and natural gas.

As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods.

Instead of burning the loose biomass fuel directly, it is more useful to compress it into briquettes (compressed block of coal or biomass material), bales and pellets thereby increase its usefulness and convenience of use. Such biomass in the dense briquetted form can either be used directly as fuel instead of coal in the traditional chulhas and furnaces or in the gasifier. Gasifier converts solid fuel into a more convenient-to-use gaseous form of fuel called producer gas, a combustible gas consisting of carbon monoxide, hydrogen, and traces of methane. This gas mixture can provide fuel for various essential processes, such as internal combustion engines, as well as a substitute for furnace oil in direct heat applications.

1.2 Sources of Biomass

India being agriculture based country so biomass availability is not a problem in Indian villages. The third largest renewable energy resource for electrical generation is biomass.

Till date for biomass energy wood is the best source examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. Therefore it means, biomass also includes plant or animal matter that can be converted into fibers or biofuels etc.

Plant energy is produced by crops specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are wheat, which yields 7.5–8 tons of grain per hectare and it yields 3.5–5 tons of straw per hectare in the UK. The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Plant biomass can also be degraded from cellulose to glucose through a series of chemical treatments, and the resulting sugar can then be used as a first generation biofuel. The figure below shows the various available resources of biomass in India.

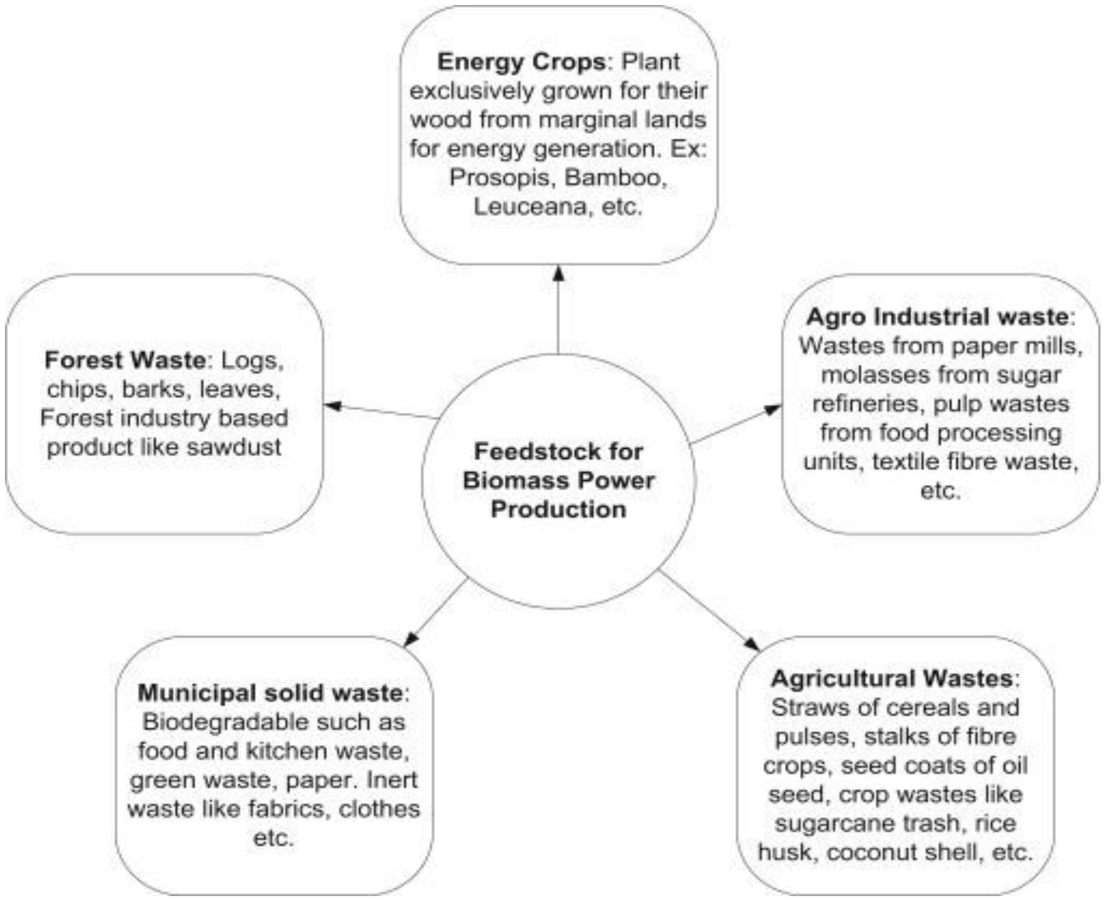

Figure 1.1: Types of available biomass resources in India

Source**:**https://www.sciencedirect.com/science/article/abs/pii/S1364032115000957

1.3 Global scenario of biomass

Biomass – the fourth largest energy source after coal, oil and natural gas is the most important renewable energy option at present and can be used to produce different forms of energy. As a result, together with the other renewable energy options, it is capable of giving all the energy services required in a present-day society, both locally and globally. The other significant characteristics of biomass are its renewability and versatility. Moreover, compared to other renewables, biomass resources are quite common and widespread across the globe.

As of now, the measure of land used for developing vitality crops for biomass powers is just 0.19% of the world's complete land zone and just 0.5-1.7% of worldwide horticultural land. Despite the fact that the enormous capability of algae growth as an asset of biomass for vitality isn't considered over in this report, there are results that show that algae growth can, on a basic level, be utilized as a sustainable power source.

Biomass is presently the largest global contributor of renewable energy, and has considerable potential to expand in the production of heat, electricity, and fuels for transport.

The supply of sustainable energy is one of the main challenges that mankind will face over the coming decades. Biomass can make a substantial contribution by supplying future energy demand in a sustainable way.

The production of biofuels as well as the introduction of power cars, has gained a lot of attention in the recent years, many studies suggest that a far more better use of plant material in the energy system is to produce electricity, and then to use that electricity for a variety of purposes, including transportation.

Like hydro power, biomass can be stored, making it a dispatchable source of power. Power generation can also be combined with heat/cooling production in (CHP) plants, which utilize a much higher share of the energy content than stand-alone power plants.

Globally the production of biomass and biofuels is on the increase due to the rising prices of fossil fuels like coal etc., growing environmental concerns and the increase in the use of renewable energy.

18% percent of the energy consumed globally for heating, power, and transportation came from renewable sources in 2017 as given in figure 1.2 below. Nearly 60 percent of this came from modern renewables (i.e., biomass, geothermal, solar, hydro, wind, and biofuels) and the remaining 7.5% from traditional biomass (used in residential heating and cooking in developing countries).

Renewables made up 26.2 percent of global electricity generation in 2018. That's expected to rise to 45 percent by 2040. Most of the increase will likely come from solar, wind, and hydropower.

The International Energy Agency puts forward that the development and exploitation of renewable energy technologies will depend mostly on government policies and financial support to make renewable energy cost-competitive.

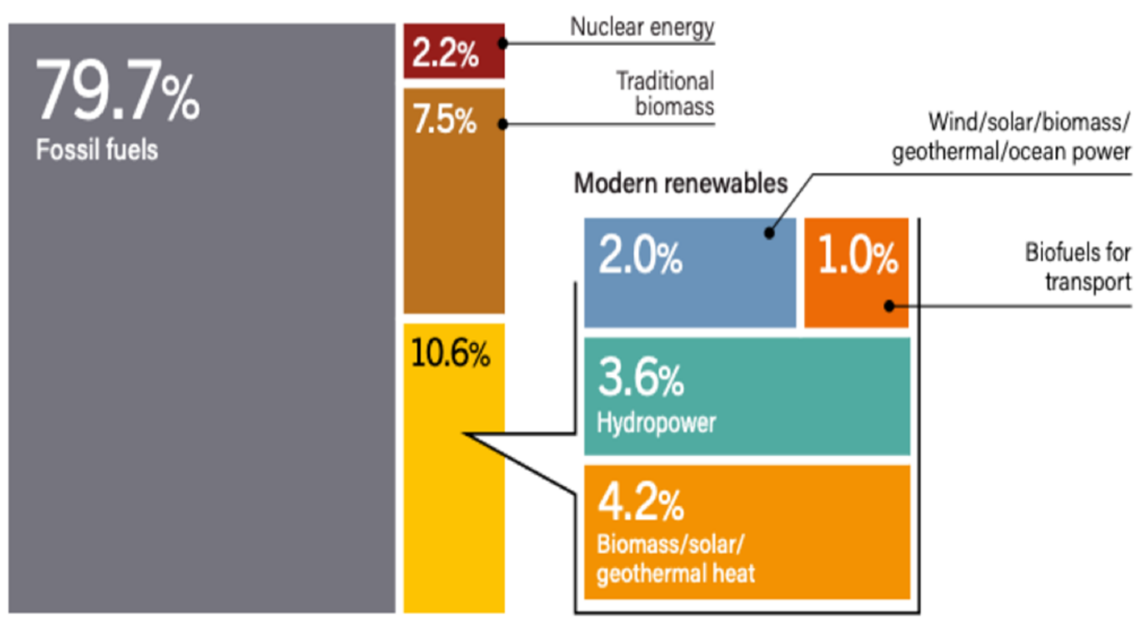

Figure 1.2: Global Renewable Energy Share

Source: Renewable Energy Policy Network

Biomass is an important source of energy contributing to more than 13% of the global energy supply. About 38% of such energy is consumed in developing countries, especially in the rural and traditional sectors of the economy.

Latest studies show that biomass energy is contributing 150-200 EJ/year by 2050, due to which less CO_2 is emitted in the environment. According to previous global energy scenarios there is a rising trend towards the use of biofuel, at small or no additional cost, and Latin America and Africa are becoming the large net exporters of liquid biofuels. World energy council (WEC) projects that 62 EJ of energy will be contributed by the developing countries in 2020. Same kind of projections are done by the International energy agency (IEA) (1998) that biomass fuels will grow at 1.2 percent per year to 60 EJ in 2020; Lazarus et al. project 91 EJ in 2030. So the common vision is that there is a large and increasing potential for biofuels all around the world and across the globe.

Finland, USA and Sweden in these countries the per capita biomass energy used is higher than it is in India, China or in Asia.

1.4 Overview of biomass power sector in India

From the conventional times biomass has been a significant non fossil and carbon free fuel for the nation, considering the advantages and promises it offers. Biomass power projects not only provide much needed relief from power shortages in the rural areas but these projects also generate employment in the villages and nearby areas.

Sources of power generation range from traditional sources such as coal, oil, lignite, and natural gas to viable modern sources such as wind, solar, biomass, nuclear and hydro. The demand for the electricity in the country is continuously rising and is expected to grow further in the near future. In order to meet this increasing demand for electricity in the country, immense addition to the installed generating capacity is required. There has been a visible impact of renewable energy in the Indian economy during the last five years. Renewable energy sector in India has experienced remarkable changes in the policy framework during the last few years.

Prime Minister Narendra Modi had set striving goal for India in the year 2015 to generate 175 Gigawatts (GW) of renewable energy by 2022. According to the most recent data released by the Ministry of New and Renewable Energy, India has installed a total capacity of 74.79 GW of renewable power as of December 31, 2018 as shown in the graph below. While India has already installed around 75 GW of renewable energy capacity, it has a long way to go if it is to meet its target of 175 GW by 2022. The average rate at which India added renewable capacity from 2015-2016 to 2018-2019 is 9.20 GW per year. Now to add another 100 GW of energy by 2021-2022, such a task would require a growth rate of over three times the current rate – nearly 33.40 GW per year. **The 100 GW goal out of 175 GW would be from solar power, 60 GW from wind, 10 GW from biomass and 5 GW from small hydro power, according to the ministry of new and renewable energy**.

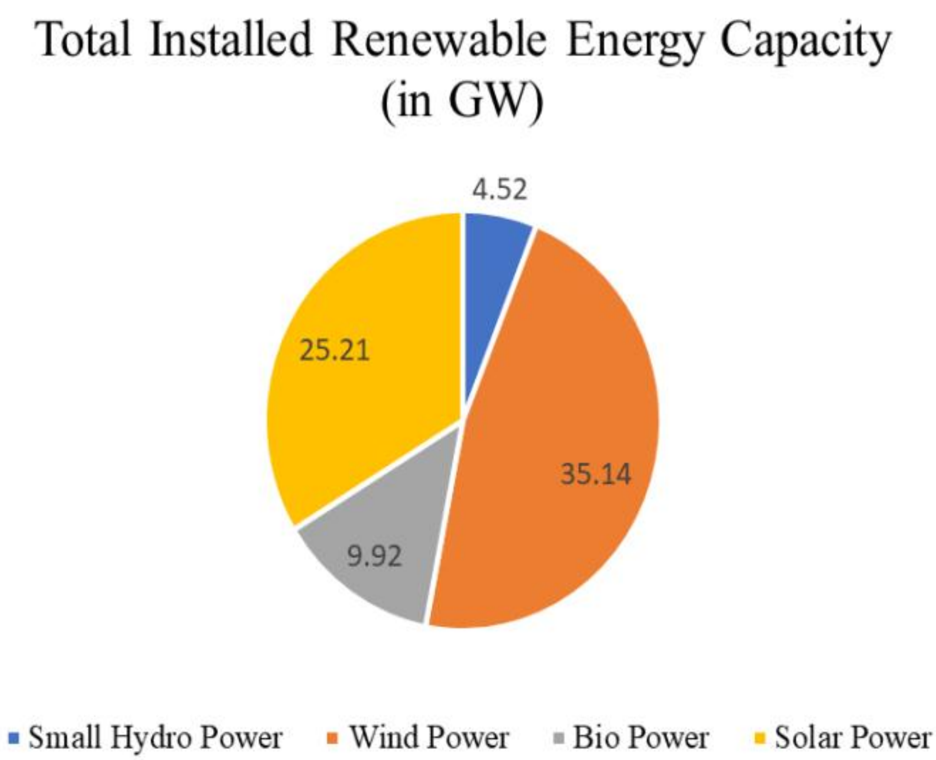

Figure1.3: Total installed renewable energy capacity in India (74.79 GW) as in 2018

Source: Ministry of New and Renewable Energy and Press Information Bureau, Government of India.

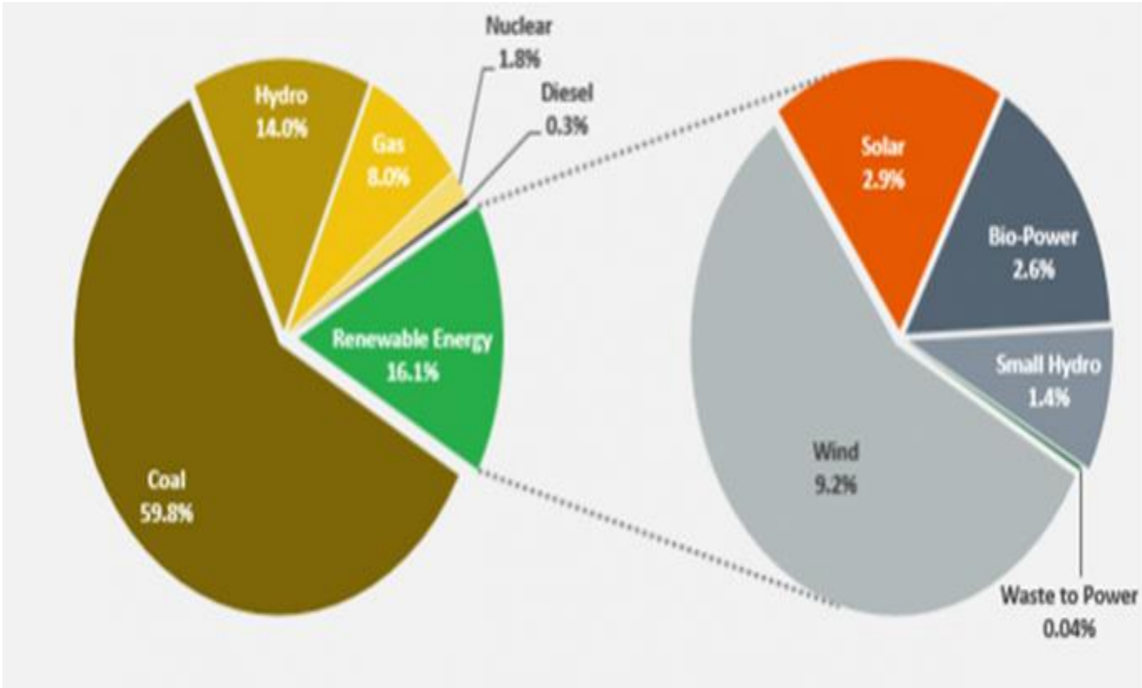

Figure 1.4: The total installed power capacity mix in India

Source:https://asian-power.com/project/exclusive/renewable-energy-jumped-16-indias-energy-mix

Renewable energy generation in India continues to grow, accounting for ~16.10 percent of India's energy mix. The country's total installed generation capacity is 315,369.08 MW with renewables accounting for 50,745 MW of it.

The Ministry of New and Renewable Energy (MNRE), Government of India has started a number of programs and schemes for the promotion of efficient biomass conversion technologies, to be used in various sectors of the country as it has realized the potential and role of biomass energy in the Indian context.

Table 1.1

Sectorwise categorization of grid based & off grid based biomass power plants

Programme/scheme wise physical progress	
Sector	**Achievements (capacity in MW as on 31.03.2016)**
I. Grid Interactive Power (Capacities in MW)	
Biomass Power (Combustion, Gasification and Bagasse Cogeneration)	**4,831.33**
Waste to Power	115.08
Sub-total Grid Interactive	**4,946.41**
II. Off-Grid / Captive Power (Capacities in MW)	
Biomass (non bagasse) Cogeneration	651.91
Biomass Gasifiers	
·Rural	18.15
·Industrial	164.24
Waste to Energy	160.16
Sub-total Off-Grid	**994.46**
Total Biomass Based Power	**5940.87**

Source: https://biomasspower.gov.in/About-us-3-Biomass%20Energy%20scenario-4.php

As can be seen in the table 1.1 above India has around 5,940 MW biomass based power plants of which 4,946 MW are grid connected and 994 MW are off-grid connected power plants. Major share comes from bagasse cogeneration in the total grid connected capacity, and around 115 MW comes from waste to energy power plants. The off-grid capacity comprises of 652 MW non bagasse co-generation, mainly as captive power plants. For meeting electricity needs in rural areas and for thermal applications in industries about 18 MW and 164 MW biomass gasifier systems are also being used respectively.

Table 1.2

State wise biomass power and cogeneration projects with capacity in MW

State wise biomass power and cogeneration projects	
State	**Capacity (MW)**
Andhra Pradesh*	389.75
Bihar	43.42
Chhattisgarh	264.90
Gujarat	55.90
Haryana	52.30
Karnataka	737.28
Madhya Pradesh	36.00
Maharashtra	1,112.78
Odisha	20.00
Punjab	140.50
Rajasthan	111.30
Tamil Nadu	662.30
Uttarakhand	30.00
Uttar Pradesh	936.70
West Bengal	26.00
Total	**4,761.00**

* - Capacity includes projects of both Andhra Pradesh and Telangana

Source: MNRE Annual Report 2015-16

After analyzing the present status of State wise biomass power and cogeneration projects it is seen that around 4761 MW of capacity is installed as per report of MNRE annual report.

Biomass is an important renewable source of energy that accounts for nearly 75% of rural energy needs, and the rural population constitutes 70% of the total population of India. Even though biomass satisfies a main part of the total energy supplies it does not find a suitable place in the energy balance of India if taken as a whole, probably due to versatility and diversity of biomass sources, resulting in insufficient availability of documented data about availability, consumption and utilization patterns.

Under the Ministry of New and Renewable Energy (MNRE), the Indian Institute of Science (IISc) has developed an electronic atlas, which provides an outlook of the biomass resources in the country with special reference to their potential for power generation. The Biomass Atlas is a graphical atlas of all the states in India with demography and land use details at state, district and taluka levels. Estimated Biomass resource and associated power potential for the categories of agro and forest & wasteland residues are provided in the table below.

Table 1.3

Estimated state wise Biomass generation, biomass surplus and power potential of Agro residues and forest & wasteland residues

State	Agro-residues			Forest and wasteland residues		
	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MW)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MW)
Andhra Pradesh	24871.7	4259.4	520.8	3601.0	2435.5	341.1
Arunachal Pradesh	400.4	74.5	9.2	8313.1	6045.4	846.3
Assam	11443.6	2436.7	283.7	3674.0	2424.4	339.4
Bihar	25756.9	5147.2	640.9	1248.3	831.9	116.3
Chhattisgarh	11272.8	2127.9	248.3	13592.3	9066.0	1269.2
Goa	668.5	161.4	20.9	180.7	119.2	16.7
Gujarat	29001.0	9058.3	1224.8	12196.3	8251.9	1150.0
Haryana	29034.7	11343.0	1456.9	393.3	259.5	36.3
Himachal Pradesh	2896.9	1034.7	132.6	3054.6	2016.1	282.2
Jammu and Kashmir	1591.3	279.5	37.1	11461.7	7564.6	1059.1
Jharkhand	3644.9	890.0	106.7	4876.6	3249.8	455.0
Karnataka	34167.3	9027.3	1195.9	10001.3	6601.0	924.3
Kerala	11644.3	6351.9	864.4	2122.1	1429.2	200.0
Madhya Pradesh	33344.8	10329.2	1373.3	18398.2	12271.2	1718.0
Maharashtra	47624.8	14789.9	1983.7	18407.1	12440.1	1741.6
Manipur	909.4	114.4	14.3	1264.0	834.3	116.7
Meghalaya	61.1	91.6	11.3	1705.9	1125.7	157.5
Mizoram	511.1	8.5	1.1	1590.9	1050.1	147.0
Nagaland	492.2	85.2	10.0	843.8	556.9	77.9
Odisha	20069.5	3676.7	429.1	9370.2	6084.6	851.8
Punjab	50847.6	24843.0	3172.1	398.5	263.0	36.9
Rajasthan	29851.3	8645.6	1126.7	9541.6	6297.4	881.6
Sikkim	149.5	17.8	2.3	531.5	350.7	49.1
Tamil Nadu	22507.6	8899.9	1159.8	4652.4	3070.6	429.9
Telangana	19021.5	2697.2	342.5	1550.7	1048.9	147.0
Tripura	40.9	21.3	3.0	1035.5	683.4	95.7
Uttar Pradesh	60322.2	13753.7	1748.3	5478.4	3672.1	514.1
Uttarakhand	2903.2	638.4	81.0	4559.2	3055.5	427.8
West Bengal	35989.9	4301.5	529.2	1430.7	949.1	133.0
Total	**511040.9**	**145105.7**	**18729.9**	**155473.9**	**104048.1**	**14561.5**

Source: https://biomasspower.gov.in/biomass-info-asa-fuel-resources.php

Most of India's' Biomass Electricity is being produced in, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and Rajasthan. New capacity is being developed in Punjab and Chhattisgarh as well. India with a total biomass capacity of around 1 GW has plans to enlarge it by 10 times to 10 GW by 2020. For supporting 1 MW of Biomass capacity around 200-600 acres of land is required which is much more than what is required for even a small thin film of solar energy, which is approx. 10 acres. The large land requirements make Biomass energy generation a tough task. However, it is of great use in niche applications where huge amount of crop and animal residue/waste is available.

1.5 Overview of Biomass in Rajasthan

The Government of Rajasthan has accorded a high priority for setting up power projects based on non-conventional energy sources in the State. With a view to promote generation of power from these sources, Government of Rajasthan issued a "Policy for Promoting Generation for Electricity from Non-Conventional Energy Sources" in 1999.

Keeping in view the requirements the policy is continuously being amended from time to time.

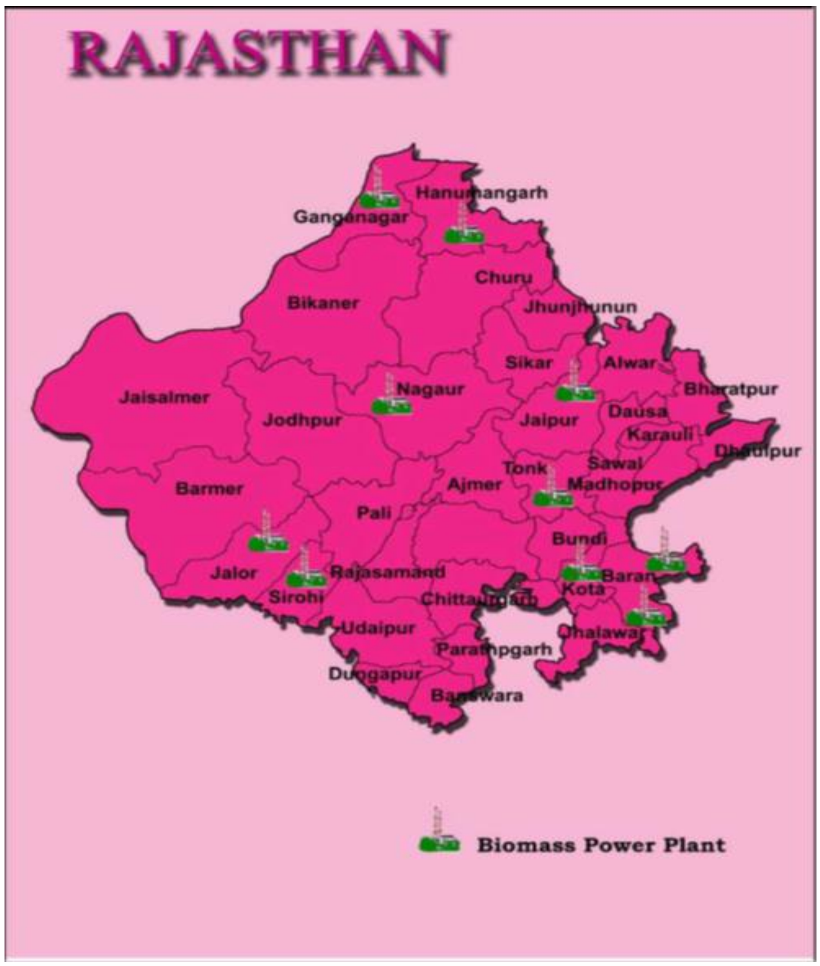

Figure 1.5: Map showing the biomass power plants in the state of Rajasthan

Source: Rajasthan biomass fuel supply study 2015

Table 1.4

District wise Generation, Consumption and Surplus amount of biomass in Rajasthan

S.No	Districts	Generation MT/Year	Consumption MT/Year	Surplus MT/Year
1	Ajmer	951594	871439	80155
2	Jaipur	2989605	2894842	94763
3	Dausa	1491207	1428451	62756
4	Tonk	1304237	1204272	99965
5	Sikar	2450096	2296200	153896
6	Jhunjhunu	1843390	1796281	47109
7	Nagaur	2141315	1983417	157898
8	Alwar	3440865	3801975	-361110
9	Bharatpur	2254803	2058979	195824
10	Dholpur	1040384	920151	120233
11	S.Madhopur	3441080	3089063	352017
12	Karoli	1375598	1216853	158745
13	Bikaner	2815399	1703236	1112163
14	Churu	1378870	850345	528525
15	Jaisalmer	480358	335533	144825
16	Ganganagar	3407664	3417693	10029
17	Hanumangarh	2921733	2751125	170608
18	Jodhpur	2195639	1200183	995456
19	Barmer	558191	361536	196655
20	Jalore	1146022	371078	774944
21	Pali	882578	637156	245422
22	Sirohi	612464	512952	99512
23	Kota	2130184	1350521	779663
24	Baran	1800015	1806866	-6851
25	Bundi	1592617	1536529	56088
26	Jhalwar	1237687	1231129	6558
27	Banswara	787063	716737	70326
28	Dungarpur	1505779	1699588	-193809
29	Udaipur	985852	963159	22693
30	Pratapgarh	769533	726971	42562
31	Bhilwara	1626567	1596597	29970
32	Chittaurgarh	1622722	1909006	-286284
33	Rajsamand	469943	850042	-380099
	Total	**5,56,51,058**	**5,00,89,905**	**55,61,153**

Source: Biomass assessment study report 2019

It was found that on an average about 92.5% of Biomass generated from the agricultural activity goes for utilisation in local for fodder, manure, brick kilns and fuel for thermal energy consuming industries, etc., and only about 7.5% is available for other activities like generation of power etc. The major portion of wheat stalks, barley stalks, paddy hay, jowar stalks, bajra stalks, maize stalks are consumed by animal as fodder and these biomass should not be used as a fuel as per the Policy of 2010. Mainly Mustard stalks, husks and soya bean stalks are used for power generation as can be seen from their generation and utilisation pattern.

Table 1.5

Generation and Consumption pattern of Biomass in Rajasthan in MT/year

S. No	Crops	Biomass	Generation MT/year	Consumption MT/year	Surplus MT/year
1	Paddy	Paddy Straw	4,20,227	420227	0
2	Jowar	Jowar Stalks	10,71,614	10,71,614	0
3	Bajra	Bajra Stalks	1,42,48,890	1,42,48,890	0
4	Maize	Maize Stalks	42,62,910	42,62,910	0
5	Moong	Moong Stalks	6,38,596	5,19,585	1,19,012
6	Urd	Urd Stalks	1,52,211	1,19,047	33,164
7	Moth	Moth Stalks	8,75,033	7,63,804	1,11,229
8	Soya bean	Soya bean Stalks	22,50,632	19,18,453	3,32,178
9	Mustard	Mustard Stalks	63,56,045	51,93,365	11,62,679
10	Cotton	Cotton Stalks	8,86,306	5,35,587	3,50,720
11	Wheat	Wheat Stalks	1,56,75,533	1,56,75,533	0
12	Guar	Guar Stalks	32,46,627	25,49,705	6,96,922
13	Castor	Castor Stems	13,50,342	8,42,628	5,07,715
14	Barley	Barley Stalks	11,62,091	11,62,091	0
15	Gram	Gram Stalks	14,14,045	10,60,534	3,53,511
16	Ground Nut	Ground Nut Stalks	16,16,475	11,73,568	4,42,907
17	Sesamum	Sesamum Stalks	2,55,938	1,76,846	79,092
		Total	**5,58,83,516**	**5,16,94,386**	**41,89,129**

Source: Rajasthan biomass fuel supply study 2015

So we can see that 41,89,129 MT per year of excess biomass is available from Agricultural Activity. More than 90 percent of the mustard husk used to be burnt by the farmers in their fields and mixed with the soil to prepare the fields for the next crop.

Sometimes the farmers had to pay money to get their fields cleaned off this waste. Even now 1.5" to 2" long stems, left in the field while manually cutting the plant, are either ploughed or burnt and mixed with the soil and thus are not being used for better purposes like converting it into energy or making proper manure for agricultural purposes.

Rajasthan Government has given special emphasis on Clean Energy Development through the setting up of the Rajasthan Renewable Energy Corporation (RREC), the State's nodal agency responsible for identification, promotion and development of non-conventional energy sources. The RREC has setup an independent CDM (Clean Development Mechanism) promotion cell for facilitation of small scale CDM projects building in renewable energy, energy efficiency and other relevant sectors. RREC also works as a nodal agency for capacity building, providing consultancy and helping entrepreneurs in earning CERs (Certified Emission Reductions). Various workshops and seminars have been organized to train stakeholders and for communicating information.

Rajasthan has immense potential in form of Juli-flora (Vilayati Babool), Mustard husk, Rice husk and other agriculture residues for the biomass fuel. Biomassbased Power Projects totalling to 113 MW have already been registered with RREC. The RREC has identified 19 locations to employ the 'Village Energy Security through Biomass', for meeting energy supplies of a village through locally available biomass resources with complete participation of the local community. The locations selected are un-electrified remote villages/hamlets of the electrified villages which could not be electrified by conventional means up to 2012.

Table 1.6

Biomass Power Potential in Various Tehsils of Rajasthan

S No.	District	Tehsil	Surplus Biomass	Tons	Power Potential in MW
1.	Sirohi	Abu Road	Caster stalks Mustard / Rap seed stalks	5287	0.25
2.	Kota	Ramganj Mandi	Maize & Mustard/ Rap seed stalks	4625	0.20
3.	Baran	Chhipa Barod	Mustard Stick/Dhaniya stalk	4008	3.00
4.	Dungarpur	Sagwara	Crop residue & Fuel wood	8642	0.45
5.	Sikar	Neem-ka-Thana	Crop residue & Fuel wood	20584	1.00
6.	Ganganagar	Gharsana	Crop residue & other sources	22066	1.00
7.	Churu	Sardarshahar	Agro-waste	37930	2.00~3.00
8.	Jalore	Bhinmal	Mustard Caster stick	108079	6.00
9.	Pali	Bali	Crop residue Fuel wood waste	69936	3.00
10.	Bhilwara	Mandalgarh	Crop residue Fuel wood waste	20166	1.00
11.	Jhunjhunu	Chirawa	Crop residue	50621	2.10
12.	Nagaur	Merta city	Crop residue	129565	5.00
13.	Barmer	Chohtan	Jeera stalk bushes	98136	6.00
14.	Bikaner	Bikaner (Khara)	Bushes Groundnut stalk	101573	6.00
15.	Jaipur	Kotputli	Crop-residue Fuel wood waste Agro-waste	28704	2.25
16.	Jodhpur	Phalodi	Bajra-moth Mustard-chilli stalks	127114	5.00~6.00
17.	Bharatpur	Roopwas	Mustard/stick & bushes	43042	3.00
18.	Alwar	Rajgarh	Crop residue Fuel wood waste	24772	1.35
19.	Tonk	Niwai	Crop residue & industrial residue	36132	1.50~3.00
20.	Sawai Madhopur	Bonli	Crop residue like Mustard and sesam stalk	36122	1.50~2.00

Source: Biomass assessment study 2017

1.6 Overview of Biomass in Kota

Kota is a city located in the south-eastern part of Rajasthan. It is located about 240 kilometers south of the state capital, Jaipur and is situated on the banks of river Chambal. Kota is one of the industrial hubs in northern India, with chemical, cement, engineering and power plants based here.

The power plants located in Kota are using all types of renewable and nonrenewable resources like water, gas, coal, and biomass as fuels for generating energy.

Biomass energy generates far less emissions than fossil fuels. Its use leads to various environment benefits. The most important one is the reduction of atmospheric CO_2 concentrations. In India the principal competing source for electricity is the coal based power. Associated with conventional electric power plants are some negative social and environmental externalities. Throughout the coal and nuclear fuel cycles there are significant environmental and social damages, contrarily biomass energy cost is highly variable depending upon the source, location etc.

The amount of total Biomass generation in Kota is 21,30,184 MT/year. Whereas, the consumption is around 13,50,521 MT/Year and so the surplus amount i.e. 7,79,663 MT/Year can be utilized for power generation. The details are given in table below.

Table 1.7

Biomass Generation, Consumption & Surplus in Kota

Biomass Generation, Consumption & Surplus in MT										
S No	**Biomass Name**	**CRR**	**Biomass generation in MT**	**Biomass Consumption (in MT)**						**Biomass Surplus in MT**
				Fodder	**Domestic Fuel**	**Manure**	**Industrial Use**	**Brick Kiln**	**Total**	
1	Paddy Straw	1.7	119550	282272	0	12	0	0	282284	-162734
2	Jowar Stalks	2.4	6464	1403	0	312	0	0	1715	4749
3	Bajra Stalks	2.63	153	97	0	0	0	0	97	56
4	Maize Stalks	2.3	12179	7974	0	63	0	0	8037	4142
5	Moong Stalks	1.25	71	7	0	14	0	0	21	50
6	Urad Stalks	1.3	20998	0	0	0	0	0	0	20998
7	Moth Stalks	1.8	0	0	0	0	0	0	0	0
8	Seasamum Stalks	1.5	2036	200	203	101	0	0	504	1532
9	Ground Nut Stalks	2.3	1086	0	0	0	0	0	0	1086
10	Soyabean Stalks	1.7	1152692	198710	0	0	0	0	198710	953982
11	Castor Stem	4	0	-	0	0	0	0	0	0
12	Cotton Stalks	3.8	5	0			0		0	5
13	Guar Stalks	1.8	90	0	0	0	0	0	0	90
14	Wheat Stalks	1.5	686102	445987	0	299906	0	0	745893	-59791
15	Barley Stalks	1.3	1039	169	0	2256	0	0	2425	-1386
16	Gram Stalks	1.1	7265	6081	0	896	0	0	6977	288
17	Mustard Stalks & Husk	1.8	120456	98768	2036	1018	0	2036	103858	16598
	Total		**2130184**	**1041668**	**2239**	**304578**	**0**	**2036**	**1350521**	**779663**

Source: Biomass assessment Report 2019- Annexure

There are around twelve companies, operating in Kota, using Biomass and coal as a feedstock for producing power. A brief description is given below:

I. DCM Shriram Ltd.

DCM Shriram is a diversified group with manufacturing facilities of Fertiliser, Chloro Vinyl & Cement in Kota (Rajasthan) and of Chlor- Alkali in Kota and Bharuch (Gujarat). The company operates coal-based captive power, facilities in Kota rated at 191 MW at Kota. Company is using Biomass and coal as a feedstock for generating power. The company has done modifications and changes in the boiler as instead of coal now the feedstock is in the form of biomass and coal both. Although Biomass has a lower calorific value as compared to coal but utilising biomass which is environment friendly has proved to be really very fruitful for the organization and for the farmers as well. If this biomass is not used as a feedstock then it will neither be eaten by the animals nor will be of any use to the farmers so it will be left over in the fields and burnt away by the farmers which will again create pollution and other hazards in the atmosphere.

In biomass the problem of adulteration is quite severe. To overcome this problem the company is using mud separator which removes mud, sand, stones and other such particles from biomass making it suitable to be used in the boiler. This equipment has proved to be very useful for them. This is a great innovation for companies procuring biomass as a feedstock for power generation.

One of the Sr. Manager told us that using biomass is very challenging for them as it is very light in weight, difficult to handle and store, it is easily blown away by wind and not available all the year round especially if the rainy season is prolonged one. Now they have developed various methods and processes to overcome these challenges. They have installed an additional belt conveyor to feed biomass from stock yard to boiler. Also, they have developed warehouses for storage of biomass in nearby villages.

II. Shriram Rayons Ltd.

Another major company in Kota is Shriram Rayons, it is a major producer of rayon tyre cord and it is also generating power using Biomass and coal as a feedstock.

It has also proposed increasing captive power generation capacity to 11.2 MW from 7.2 MW. They have four boilers one is working completely on coal, another on Mustard husk and other two on coal and mustard husk both. Their daily consumption of biomass husk is around 300 MT. The price of Biomass husk at factory gate is approx. 3000Rs./MT which keeps on varying according to the availability of Biomass across the year which is quite less if we compare it with coal (price is around 6500Rs./MT) or any other fossil fuel used for generating power.

III. Kalpataru Power Ltd

Kalpataru Power is one of the largest and fastest growing specialized EPC companies in India engaged in power transmission & distribution, oil & gas pipeline, railways, infrastructure development and warehousing & logistics business with a strong international presence in power transmission & distribution. The company is currently executing several contracts in India, Africa, Middle East, CIS, SAARC and Far East. Biomass power plants are an integral part of inclusive development at Kalpataru Power as these projects generate rural employment as well as contribute positively to a greener environment by converting waste materials into clean energy.

The company has set up a Biomass plant at Padampur in the Ganganagar district of Rajasthan in 2003. This plant uses agricultural waste and crop residues (biomass) as inputs and generates 7.8 MW of power. Kalpataru Power has set up another biomass plant in Tonk District of Rajasthan in 2006 of 8 MW capacity. This plant also uses agriculture waste and crop residues (biomass) as inputs. Both Plants have logistics infrastructure to collect approx. 200,000 MTs of such inputs every year.

IV. Surya Chambal Ltd

Surya Chambal ltd, is a 7.5 MW capacity biomass (mustard husk) based power plant, located at Rangpur Village of District Kota, about 8 kms from Kota railway station on the banks of the river Chambal. The project was started in April 2004 and the plant was commissioned and synchronized with the Rajasthan Power Grid at 33 KV on 31st

March, 2006. Thus starting the supply of power through its Gopal Mill GSS situated near Kota railway station. The company is now expanding and putting up another unit of 10 MW at Khatoli village in Kota, about 100 km from Rangpur. Its sister concerns, Sathyam Power Pvt. Ltd. is putting up a 10 MW plant at Merta Road in Nagaur district and Prakriti Power Pvt. Ltd. is putting up a 12 MW Power Plant at Gangapur city in SawaiMadhopur district.

The company has never used fossil fuel to support biomass for the plant and purchases Rs.10~12 crore of biomass annually and thereby generates income for farmers and others in a region of 50 km radius from the plant. The company faced initial teething troubles. However, after carrying out certain technical modifications, it started yielding satisfactory results.

V. Orient Green Power Company Rajasthan Pvt Ltd

Another company operating near Kota is Orient Green Power ltd located in Kishanganj which is in Baran district near Kota. They are using Mustard husk as a feedstock for generating power. The company faced initial problems while setting the project. However, after carrying out certain technical modifications, it started yielding adequate results. They have developed additional infrastructure for feeding the biomass in the boiler and for handling the biomass.

VI. Goyal Proteins

Goyal Proteins is another such company in Jhalawar near Kota which is also using biomass mustard and soya bean husk as a feedstock for generating power. Goyal Group of Industries is the epitome of premium quality edible oil manufacturers. They are the trusted name behind renowned brands. Being a quality driven group, they have a perfect blend of excellence and quality as they procure selected oil seeds from reputable vendors of the industry. They use latest processing equipments for accomplishing the targets.

VII. Ruchi Soya Industries Ltd.

These companies are producing power using the mustard husk of biomass. Ruchi Soya Industries Limited. (Ruchi Soya) is a leading manufacturer and India's largest marketer of healthier edible oils, soya food, premium table spread, Vanaspati and bakery fats. They emerged as an integrated player, from farm to fork with open access to oil palm plantations in India and other key regions of the world.. They are diversifying into various other businesses like generating power and they are also the highest exporter of soya meal, lecithin and other food ingredients from India.

VIII. Shiv Edible Ltd.

Shiv Edible Industries are located in Ranpur in Kota. They have attained complete client satisfaction and recognition amongst the best and the most reliable manufacturers of Agro Products in the nation. They are using biomass husk for generating power and are helping farmers and middlemen in having an extra income from the business of biomass.

IX. S.M. Environmental Technologies Pvt. Ltd.

They have a plant of 8 MW at Kishanganj Baran which is utilizing mustard husk as a feed stock for generation of power. Their other portfolio includes biogas, wind energy and small hydroelectric projects at various stages of development. As on January 2014 their portfolio of operating projects included 506.205 MW of aggregate installed capacity, which comprises 420.205 MW of wind energy projects and 86 MW of biomass Projects.

X. Sharda Solvent Ltd

Their company is using mustard husk as feedstock for generating power. Initially they faced problems of availability of biomass as many companies came up in their proximity but slowly and slowly they established the network of suppliers due to which things went on smoothly.

XI. Shriram EPC

The company has many portfolios like Process & Metallurgy, Power, Water Infrastructure and Mining & Mineral Processing. They use biomass husk for generation of power which they procure locally from the farmers and vendors. The prices of biomass husk are continuously increasing, this is due to large number of companies are venturing into this business so the problem of timely availability of the husk is there.

XII. Mangalam Cement

Apart from making cement, waste heat recovery plants (WHR) are generating power of 5.15 MW capacity and another of 5.85 MW capacity. They have established themselves into this business from last many years so a good network of suppliers have been established and using new technologies & innovating new equipments for feeding husk into the boiler have made them stay amongst significant players.

Since the biomass is available in surplus amount in Kota and nearby areas, there is a huge potential for generation of power using Biomass as feedstock by the power producing companies.

1.7 Biomass potential

Biomass has very high potential for business growth and it is also providing opportunities for mass employment as well. It is one of the leading source of primary energy for most of the countries as it is characterized by low cost technology and freely available raw material.

Biomass provides business opportunities in various sectors like R&D, Engineering procurement and construction(EPC), Agriculture (biomass cultivation and processing), transport services, bioenergy generation, core equipments manufacturing etc. as shown in the below representation.

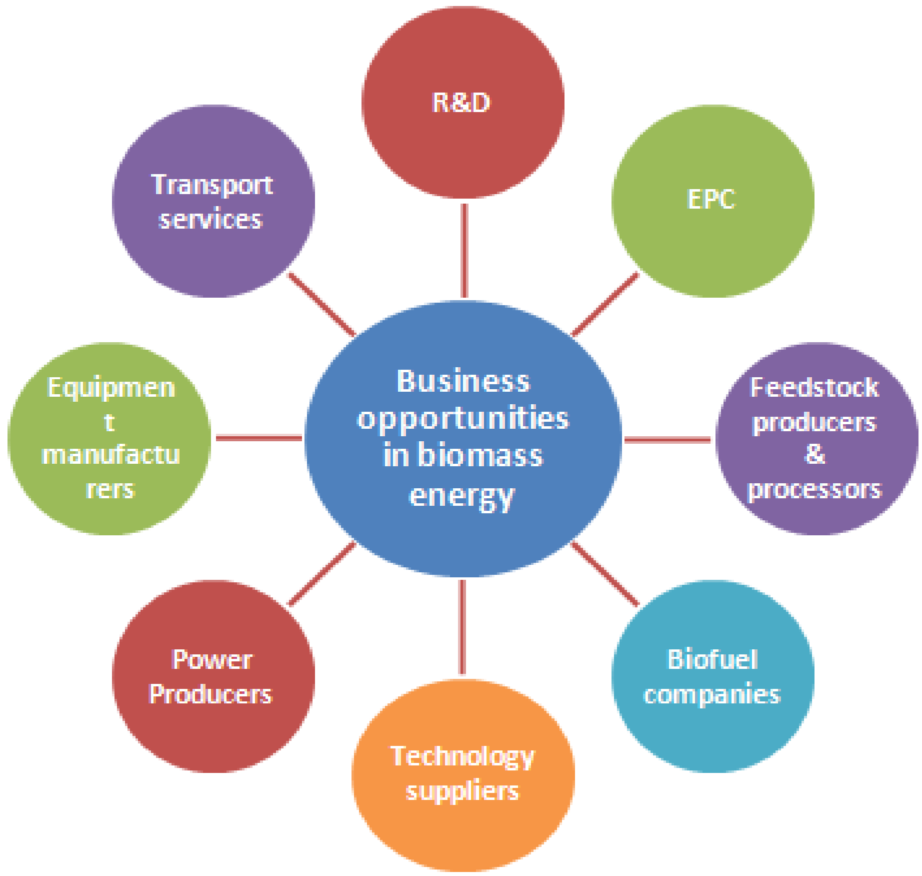

Figure 1.6 Opportunities in Business related to biomass energy

Source: http://www.eai.in/ref/ae/bio/biz/biomass_biz_opp.html

Biomass has a large energy potential. Globally if we see the current biomass use is clearly below the available potential. In Asia the scene is a bit different the current use of biomass exceeds the available potential, i.e. non-sustainable biomass use. As a result, biomass use can be increased and energy can be generated to a larger extent throughout the world. The future demand for renewable energy can be covered, by greater utilization of forest remains and remains from the wood processing industry.

Renewable transportation fuels from biomass have the potential to considerably reduce greenhouse gas emissions and extend global fuel supplies. Thermal conversion by fast pyrolysis converts up to 75% of the starting plant material (and its energy content) to a bio-oil intermediate suitable for upgrading to motor fuel.

Woody biomass is mostly preferred in thermo chemical processes due to its low ash content and high quality bio-oil produced. However, the availability and cost of biomass resources, e.g. forest residues, agricultural residues, or dedicated energy crops, vary greatly by region and are the key determinates in the overall economic feasibility of a pyrolysis-to-fuel process.

India has a potential of about 18 GW of energy from Biomass. At present, about 32% of all out essential energy utilized in India comes from Biomass. Over 70% of the nation's population relies on biomass for its energy requirements.

There is high potential for generation of renewable energy from various sources wind, solar, biomass, small hydro and cogeneration bagasse. The total potential for renewable power generation in the country as on 31.03.17 is estimated as 10,01,132 MW. This includes solar power potential of 6,49,342 MW (64.86%), wind power potential of 3,02,251 MW (30.19%) at 100 m hub height, SHP (small-hydro power) potential of 21,134 MW (2%), **biomass power of 18,601 MW (1.86%)**, 7,260 MW (0.73%) from bagasse-based cogeneration in sugar mills and 2554 MW (0.26%) from waste to energy.

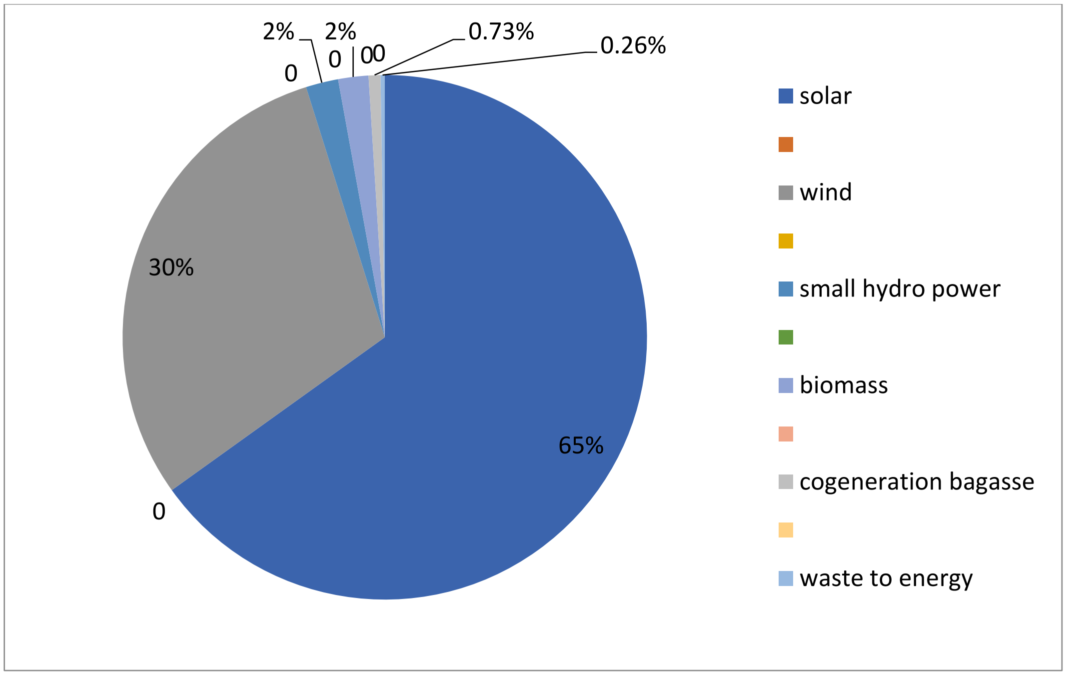

Figure 1.7: Estimated Potential of Renewable Power in India(Source wise) as on Mar'17

Source: Energy Statistics 2018

1.8 Biomass fuel and its properties

Biomass contains carbon, hydrogen and oxygen. It also contains small amounts of nitrogen and small quantities of other atoms, including alkali, alkaline earth and heavy metals. The chemical composition of biomass varies among different species, but in general biomass consists of 25% lignin and 75% carbohydrates or sugars.

Methane gas or transportation fuels like ethanol and biodiesel can be very easily made from biomass. Decaying garbage, agricultural and human waste, all discharge methane gas—also called "biogas" or "landfill gas".

Biomass is available in a number of different formats like fine dust, sawdust, chips, pellets, briquettes, and bales.

Chips and dust are the formats which requires vey less post-harvest processing and also cost very less when used as a fuel if production is available locally.

Chips can be milled to form wood dust (sawdust). We can store them in open for very long hours if continuous monitoring is done regarding self-ignition and heating. The bulk density of chips is comparatively lower than that of pellets, so their transportation will be more expensive per unit of energy.

Pellets and briquettes are generally more cost effective to transport due to their higher bulk density of typically 600–700 kg/$m^3$and are less prone to "hang-up" in the bunkers and conveyors but it is more expensive to produce them as compared to chips. Pellets are bio-fuel compressed into small cylinders with a typical diameter of 5–15 mm and a length of 10–50 mm.

Figure 1.8: Pellets of Biomass

Source: https://www.indiamart.com/proddetail/biomass-pellets-7047325955.html

Biomass can also be delivered to the power station in bales. This format is mostly used for straw and special equipment is required to remove the strings and break up the bales or a plant is designed specially to burn the bales. Bales are comparatively easy to transport and their bulk density is also good. They can also be stored in the open for shorter periods of time. A modern large bale can weigh up to 300–500 kg.

Figure 1.9: Bales of Biomass

Source:https://www.canr.msu.edu/news/storing_biomass_in_round_bales

Another form in which biomass can be stored for future use is the biomass briquettes. Instead of coal and charcoal their substitute i.e. biomass briquettes can be used as a bio-fuel substitute. Briquettes can be used in the areas, where it is difficult to find fuels used for cooking. In the developed countries use of briquettes is done quite often, to heat industrial boilers in order to generate electricity from steam. The briquettes are co-fired with coal and the heat produced is transferred to the boiler.

Biomass briquettes are the compressed form of biomass mostly made of agriculture waste and other organic materials, used for heating purposes, as a cooking fuel and for power generation. Various organic materials, like rice husk, ground nut shells, bagasse, agricultural waste and municipal solid waste together make the briquettes. According to the availability of raw materials, the composition of the briquettes varies from one region to another. The raw materials are collected and condensed into briquettes in order to burn them for a longer time. The briquettes when burnt produce less greenhouse gas emissions in comparison to fossil fuels like coal etc. as the raw materials used are already a part of the carbon cycle.

Figure 1.10 Biomass Briquettes

Source: https://en.wikipedia.org/wiki/Biomass_briquettes

Today in modern times biomass is not used to the extent it was used in traditional times. In the developed countries biomass is again becoming very significant for applications such as combined heat and power generation. In addition, biomass energy is having a good potential to be used for power generation and as a source of clean heat for domestic heating and community heating applications.

1.9 Biomass based power generation

In today's time electricity is a basic necessity for not just the developed world, but also for the developing countries like Indonesia, Afghanistan etc. and for the underdeveloped nations like Mali, South Sudan etc. Still the feed stocks used for power generation are mostly dependent on fossil fuels, which are nonrenewable in nature and which will soon be depleted and exhausted from the environment. They will also create pollution in the form of Greenhouse emissions which will in turn harm the ozone layer leading to global warming.

The countries across the globe should now start using more and more greener and renewable fuels for power generation. To derive power directly or indirectly variety of biomass is used and there are also manifold pathways to produce power using biomass,

It is imperative for India too, to start using more of renewable energy sources as there are serious concerns related to pollution and global warming across the world. More and more sources of renewable energy should be explored by our country, which can generate power in a distributed way and on small scales, so that more than 60,000 villages that have no access to electricity can get benefit from it. It is at this place where biomass based combustion power, and particularly biomass gasification based power would be used.

1.9.1 Primary Routes for Power from Biomass

Combustion, Gasification and Anaerobic Digestion are the three primary routes for conversion of biomass to power:

- Combustion of biomass for generation of power could either be in the form of co-firing (when it is burned along with coal) or purely biomass based combustion where no mixing of fuel is there in the feed stock, only purely biomass is feeded into the boiler.

- In the process of biomass gasification the biomass is first burned in a very controlled supply of air to form a gas consisting of various other gases like carbon dioxide, hydrogen, carbon monoxide and other such related gases and some contaminants, and this gas is then cleaned for use in boilers and turbines to generate heat and power.

- Kitchen waste, sewage waste and other organic wastes are used for producing energy through anaerobic digestion. In this process the microbes act upon the untreated matter present in the biomass under anaerobic (absence of air) conditions and convert it into biogas,

Pyrolysis is a forthcoming route for biomass based power. In this, process of pyrolysis the biomass is swiftly heated to very high temperatures of about 450 - 600°C in the absence of air, which ends up with an output known as bio-oil also called the pyrolysis oil, which can again be used for firing the boilers.

1.9.2 Benefits of biomass based power generation

- Distributed generation of biomass power

Biomass is very easily available everywhere across the globe in the form of agriculture residues or wastes of many forms especially in rural areas and country sides. The process of gasification based power generation can be done on small scales (as low as 20 kW) and this method can be used for distributed generation of power as against the centralized power production method which is mostly used in todays' era.

- Continuous power generation

Continuous power generation is possible with biomass energy sources as biomass can be made available anywhere and anytime. Such plants which provide continuous power generation are called base load power plants, they are only turned off during periodic maintenance, upgrading, overhauling or servicing. Solar and wind energy sources provide unsteady and uneven supply of energy so they cannot as be used for continuous power generation.

- Suited for villages and rural areas

For villages situated in remote areas where there is no access to grid but large and bulky amounts of biomass are available, biomass based power generation is very good means of having access to the basic necessity of electricity.

- Capacity to have small, KW scale power production

Sources of power like thermal and nuclear require larger scales for generation of power whereas biomass gasification based power production can be done at small scales – as small as 20 KW. This is ideally suitable for smaller villages that are having only a few households.

- Rural economic upliftment

The prosperity of rural areas increase as employment and opportunities are generated for the rural masses by installing the power plants for power generation and also a very efficient supply chain starts beginning from the farmer to the customer. For generating 1 MW power from biomass around 200-600 acres of land is required so the opportunities for rural employment are certainly significant.

- Ecofriendly

Biomass power also emits carbon like coal and other forms of nonrenewable fuels emit carbon on burning, but this carbon emitted is taken back by the plants during photosynthesis, so biomass based power generation is also called carbon neutral. Biomass power is ecofriendly and due to it the atmosphere is also pollution free.

- Proper utilization of renewable organic resources

Biomass power generation is an efficient process which results in the use of mostly animal and crop wastes which if not consumed in a proper manner would be converted into carbon dioxide in the atmosphere.

- Multiple feedstock

Large variety of feedstock such as wood pellets, mustard husk, soya bean husk, rice husk, bagasse etc. can be used to generate biomass power. If these crop residues are left over in the fields, they are of no use to the farmers and they in turn burn the husk and the crop stubble (parali) which creates pollution in the atmosphere.

- Resource of Low Cost

Biomass power can be generated cost-effectively which can be competitive to grid power, if there is regular and good availability of feed stock.

1.10 Supply chain of Biomass

Biomass energy production requires the flow of biomass material from the land to its ultimate end use. Along the way, biomass passes through a series of processes in what is called the biomass supply chain.

Various elements of the biomass supply chain require unique sets of information, knowledge, technology and activity. These include growing, harvesting, transporting, aggregating, storing and converting biomass. Depending on the energy and the biomass type pre-processing may also be an important step along the pathway from the land to energy use.

Transport, storage and handling are key issues throughout the supply chain and link the various segments to each other. The various stages along the biomass supply chain are frequently interdependent and interconnected, with changes in productivity and technology in one stage affecting that in other stages.

Several key issues influence the entire biomass supply chain: existence of biomass markets, getting connected to markets, and supply logistics. All these activities are made possible by the farmers, middlemen and the employees of the power generating company. They are the key stakeholders of the supply chain.

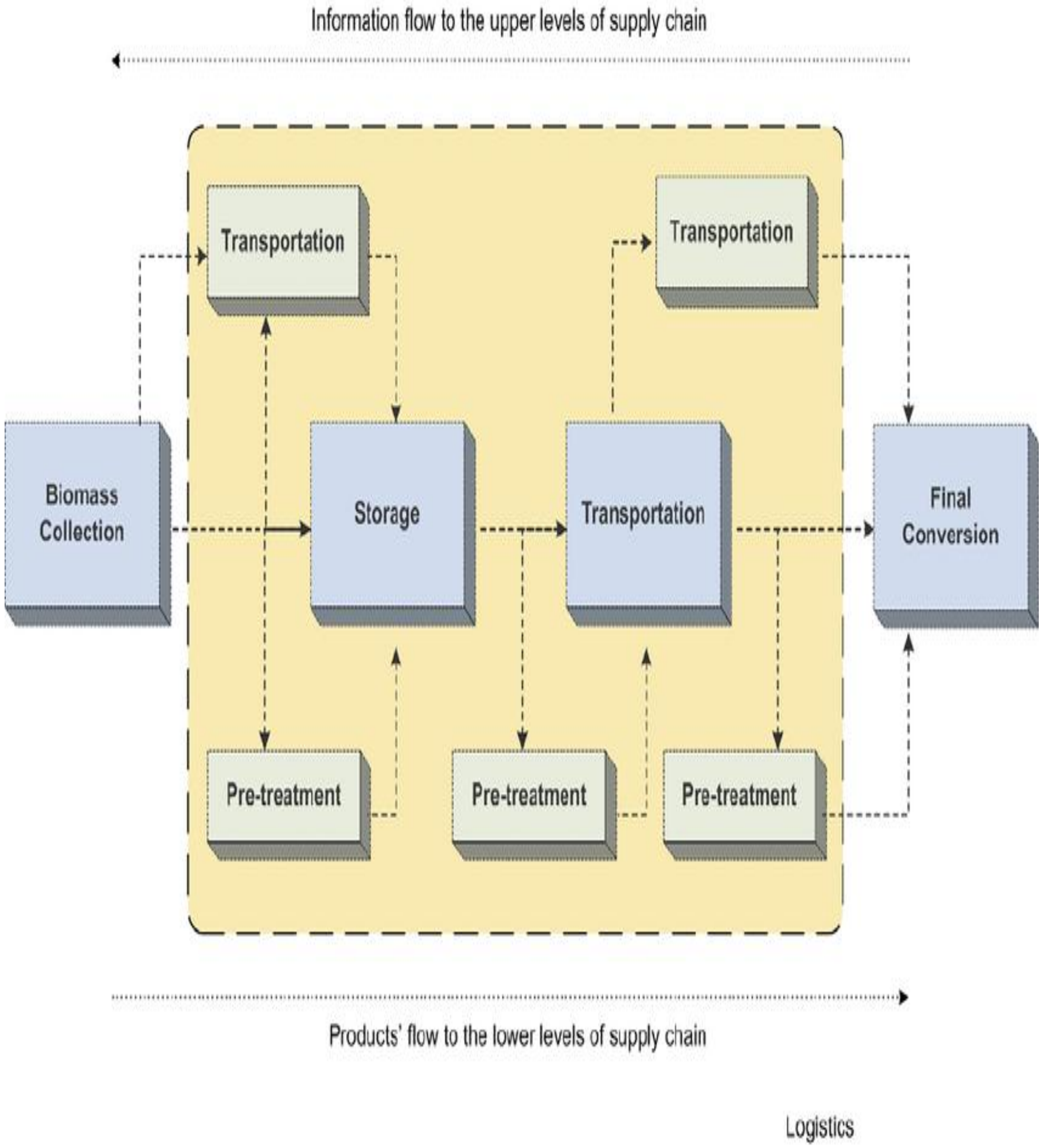

Figure 1.11 Supply chain of Biomass

Source: https://www.researchgate.net/figure/Graphical-Representation-of-a-Biomass-Supply-Chain-BSC_fig1_266486110

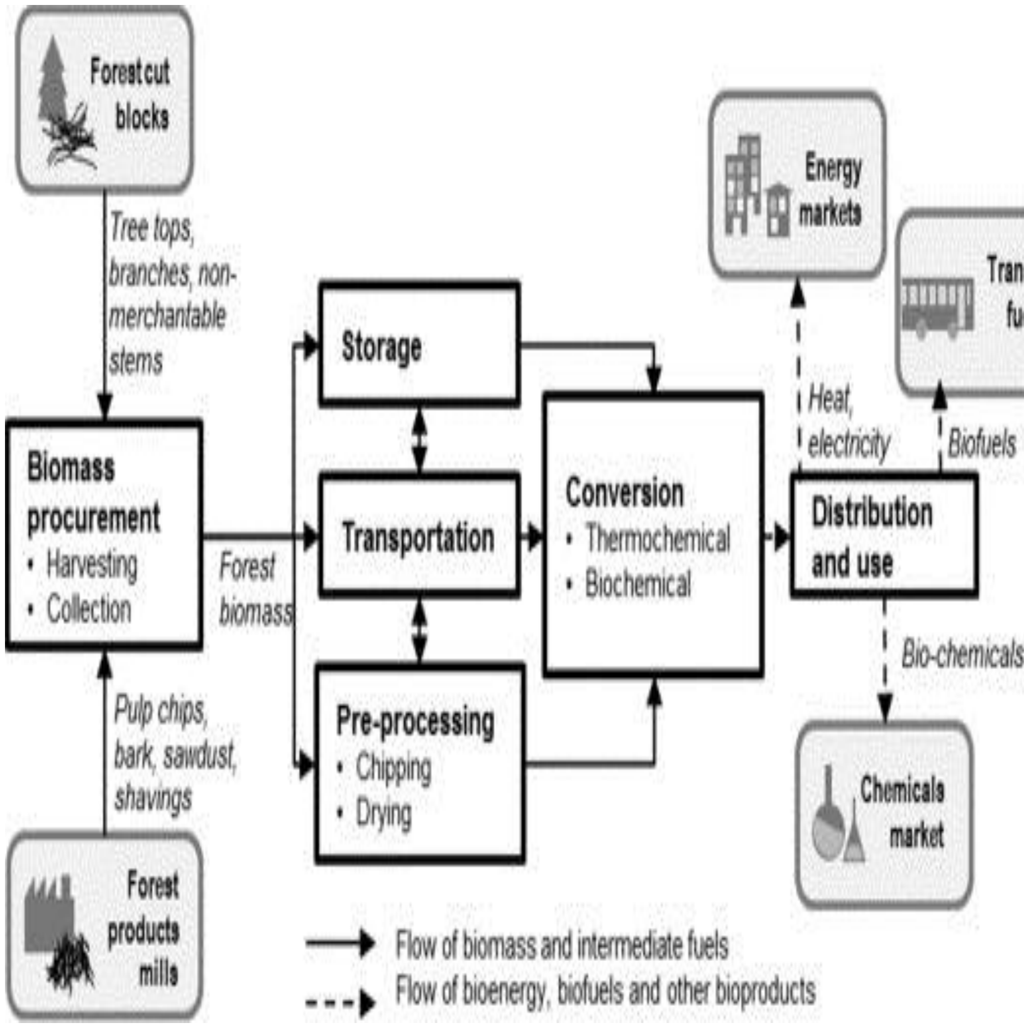

Figure 1.12 Biomass supply chain in Forest area

Source: https://www.sciencedirect.com/science/article/abs/pii/S1364032114002688

The biomass supply chain is made up of a range of activities which include harvesting, baling, storing, drying and transport of the biomass both on the field and to the bio refinery, handling and transport of residues and by products. The activities required to supply biomass from its production point to a power station are as follows, which are also depicted in the above figures:

- Harvesting/collection of the biomass in the field/forest.

- In-field/forest handling and transport to move the biomass to a point where road transport vehicles can be used.

- Storage-Many types of biomass are characterized by seasonal availability, as they are harvested at a specific time of the year but are required at the power station on a year-round basis; it is therefore necessary to store them. The storage point can be located in the farm/forest, at the power station or at an intermediate site.

- Loading and unloading of the road transportation vehicles. Once the biomass has been moved to the roadside it will need to be loaded to road transportation vehicles for conveyance to the power station. The biomass will need to be unloaded from the vehicles at the power station.

- Transport by road transportation vehicles. There are varying opinions in the literature and studies available on whether it is more economical to use heavy goods vehicles or agricultural/forestry equipment for biomass transport to the power station. Ultimately, it appears to be a matter of the average transport distance, biomass density, the carrying capacity and travelling speed of the respective vehicles, and the availability of the vehicles.

- Processing biomass to improve its handling efficiency and the quantity that can be transported. Processing can occur at any stage in the supply chain but will often be done before transportation and it generally costs very less when combined with the harvesting. The various stages are depicted in the below figure:

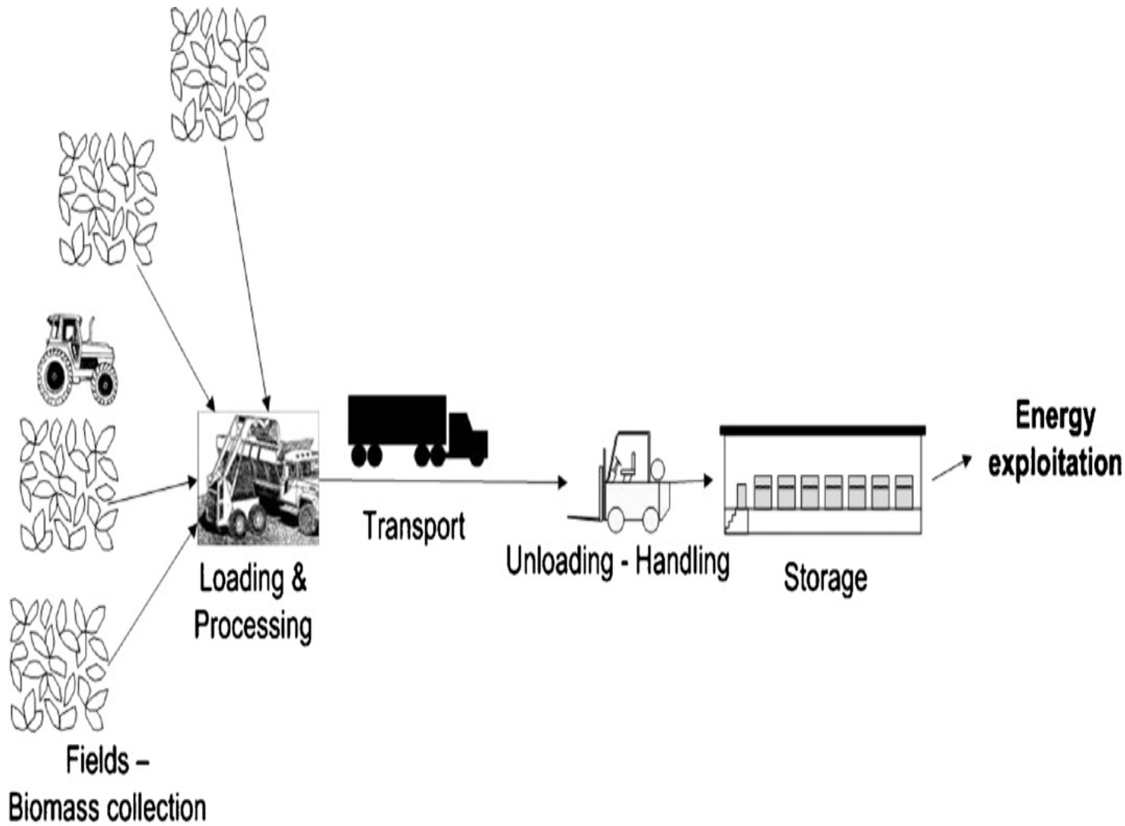

Fig 1.13 Basic biomass supply chain design

Source: https://www.researchgate.net/figure/Generic-biomass-supply-chain-design_fig1_223824022

The whole network which operates in time and space that coordinates, in order to estimate the logistics costs, a global view of the processes, which are strongly interlinked, is needed. The main characteristics of the supply chain, that influence the logistics efficiency, are that the raw materials are produced over large geographical areas, have a limited availability window, and often are handled as very voluminous material.

The statistics shown with respect to various aspects like globally, in our country, in our state Rajasthan and in our city Kota shows that on an average biomass is available in surplus and its use is also increasing day by day which is the need of the hour.

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CHAPTER-2

Review

of

Literature

2.1 Introduction

The Literature review provides an account and consolidation of the most relevant literature in the fields of renewable energy especially related to biomass. A review of literature of various studies related to Biomass as an energy fuel, a source of power generation and its effective logistics and supply chain management shows that very limited research has been carried out in this area especially in the Indian context. Various International and National Research papers were studied and reviewed to find out the research gap. Areas of Literature reviewed in this chapter include biomass for bioenergy and biofuels, biomass for power generation and supply chain management of Biomass.

2.2 Research related to Biomass for Bioenergy and Biofuels

Vlosky and Smithhart (2011) have stated that Biomass has a large energy potential. Only about two-fifths of the existing biomass energy potential is used if a comparison is done between the available potential with the current situation, on a global level. Current biomass use is clearly below the available potential in most areas of the world. However, in Asia, the current use exceeds the available potential, i.e. non-sustainable biomass use. The subtropical and tropical forests comprise 56% of the world's forests, while boreal and temperate forests account for 44% (FAO, 2001). For growing biomass tropical countries are having favorable conditions. However, issues related to optimal use of biomass as an energy source are still to be resolved. Still some main issues are there like lack of information and technology transfer and some legal and institutional barriers. Furthermore, common misapprehensions about biomass energy have to be taken care of. They have signified that the larger part of wood fuels is coming from non-forest land; the root cause of deforestation is not the use of wood fuel.

Therefore, increased biomass use, e.g. for upgrading is possible in most countries. A possible alternative is to cover the future demand for renewable energy, by increased utilization of forest residues and residues from the wood processing industry, e.g. for production of densified biofuels (Parrika, 2004). They have concluded in their paper that the tropical Asian countries have a large potential for biomass production. It is expected that under the initiatives of both industrialized countries and tropical Asian countries, through Clean Development Mechanism (CDM) schemes various projects of large scale energy crop production (e.g. cassava, oil palm, sugar cane, etc.) will be implemented in the near future.

Mohapatra and Gadgil (2013) have stated in their studies that growth of civilization with rapid increase in energy utilization through severe energy crisis has shifted the attention towards renewable resources i.e. biomass. Terrific growth in population has increased the energy consumption at such a rate that an alternate route for energy generation has become a very essential requirement. This is where the role of renewable energy systems comes in. Biomass is considered as the renewable energy source with the highest potential to contribute to the energy needs of today's society. This is the only replenishable source which could generate energy and feedstock approx. 14% of the renewable energy is in the form of biomass energy.

Biomass is not only a source of renewable energy but also a source of petrochemical and chemical feedstock. Many new technologies are available which can convert biomass into thermal and electrical energy. If biomass is consumed in a proper way then it can replace the consumption of fossil fuels to a great extent. Generation of power through biomass is carbon neutral as the amount of carbon released on its combustion is taken back by the plants in the form of carbon dioxide. Conventional sources of energy are going to deplete sooner or later. So it is important to shift to new and modern sources of energy.

Various experiments were conducted in the laboratory with wood chips and saw dust and as standard biomass to convert it into valuable products.

This paper describes the different routes along with the experimental studies that have been undertaken towards achieving the goal of converting biomass into useful energy. Research should be diverted towards the formation of value added chemicals from bio-mass rather than the use of biomass as direct fuel. Government subsidy is also necessary to improve the economic viability of the above technologies. The current energy scenario demands the need of alternate sources of energy. However complete switching to cleaner source is difficult to achieve because of the economic, technical and social constraints. The existing technologies have many merits and demerits. Thus it may be concluded that there are many possibilities as well as restrictions in the use of biomass in energy supply.

Osman et al (2014) have reviewed about forestry biomass in their research article with main emphasis about Malaysia. Forestry biomass is a material particularly derived from plantation forest, rubber plantation of Malaysia natural forest, material gathered from log production and major wood manufacturing activities. The information helps to anticipate the potential of these promising waste resources to be used for energy products. In Malaysia the tropical and humid climate throughout the year provides significant opportunity to tap this resource completely. Supplementing vitality sources from timber land biomass is another approach to help its population. This paper aims to estimate waste generated and to calculate their energy value from these particular materials and ultimately, to forecast the potential of this feedstock. The word biomass and energy are the same and bioenergy is been used interchangeably in our day to day life. The generation of energy from woody biomass has become intense in Malaysia as supported by "National Biomass Strategy 2020". From previous section it has been concluded that the amount of woody biomass material available is not so important but the amount of energy that can be generated from it is more valuable. The energy content of biomass is always reported as dry biomass, and the term higher heating value "HHV refers to the energy released in combustion when the water vapour resulting from the combustion is condensed thus realizing the latent heat of evaporation" meanwhile the lower heating value or "LHV reports the energy released when the water vapor remains in a gaseous state".

Mahar etal (2012) have discussed in their paper how waste agricultural biomass (WAB) can be used as source of energy for industrial and domestic purposes in Pakistan. In respect of this vision, nine WAB samples were taken from district Sanghar and analyzed as per standard methods for the level of moisture content, for total solids and for volatile solids by thermo-gravimetric analysis (TGA). The results pointed out that WAB has remarkable energy potential in terms of methane, which can be utilized for cooking, heating and power generation purposes. Biomass can be converted into a variety of energy forms which includes heat (direct burning), electricity (steam and gasification), ethanol, hydrogen and methane. Number of factors like conversion efficiencies, energy transport, economics, and type of technology and environmental impact of conversion process are to be considered while converting biomass into various forms. Methane is an ideal fuel in most circumstances.

In this paper importance of Biogas and digested substrate, and their advantages for the society were also discussed. Biogas can be utilized for several purposes. The simplest use of biogas is that it can be directly used for cooking and lighting. It can also be used for combined heat and power generation (CHP).

Generation of digested substrate creates new jobs related to the collection and supply of feedstock, manufacture of biogas plant equipments, construction, operation and maintenance of biogas plants etc. In Pakistan, many domestic bio gas plants are in operation but their feedstock is the dung of buffaloes and cows. In developed countries there is good number of commercial as well as farm scale biogas plants in operation with a feedstock of animals dung and WAB, but in Pakistan practice of using the co-digestion of WAB with animal dung is not there. Huge quantity of WAB is wasted in district Sanghar. This analytical study has been carried out for the first time in order to highlight the benefits of the biogas from WAB and its potential in Pakistan.

Blaschke and Biberacher et al (2013) in their paper have examined the ways in which future 'energy landscapes' can be modeled in time and space. Biomass is an energy carrier that may be purposely useful in circumstances where other renewable energy carriers are likely to deliver less. An important issue considered in this article is whether an immense expansion in the use of biomass will allow us to create future scenarios while repositioning the 'energy landscape' as an object of study. A second important issue is the exploitation of heat from biomass energy plants. Biomass energy also has a larger geographical footprint than other carriers such as, for example, solar energy. This article tends to provide a link between energy modeling and territorial planning.

"Energy landscapes" provides a link between physics-based views on energy supplies and their geographical footprints on one hand, and the 'energy landscape' concept and how common men think about geographic space on the other hand. Such "energy landscapes" may in future become a valid understanding concept for territorial planning and may provide geographical analysis capabilities and methods with which to plan future action. The authors consider their framework to be a starting point, targeting to inspire interdisciplinary discussions between physicists, energy experts, global geographical planners and future "energy landscape" managers. The authors conclude that most areas currently used for energy production, and specifically for bioenergy which is, again and again stated, a land-consuming form of renewable energy production were not selected to meet specific predefined goals concerning their location, quantity, and spatial display. Many existing bioenergy production areas in Austria and Germany are found in areas that are very appropriate for other purposes (such as agriculture or urban development) or were selected for their own unusual reasons.

Sathaye (2011) has pointed out in his paper that most energy efficiency technologies are cost effective and wind generation technologies are the lowest cost renewable energy sources, and that their implementation is held back by institutional, practical and process barriers. The main goal of this report is to text approaches that ensure that public policy and programs work with market forces and businesses for functioning of energy efficiency and renewable energy (EERE).

This report points out certain on-going programs and policies that are overcoming hurdles in the industrial and power sectors, and notes key issues that need to be addressed for their imitation in India. Future growth in energy demand will place considerable stress on India's ability to acquire domestic and imported energy supplies. Regular energy shortages and environmental pollution, particularly in urban areas, may be aggravated, and the country may continue to be susceptible to potential oil and gas supply disruptions, and to the instability of petroleum crude prices. Exclusive dependence on supply sources would exaggerate the energy security risk posed by such disruptions. Energy efficiency offers a lucrative solution to overcoming this threat which is almost entirely within the control of the Indian government and private sector. Building ability to plan and execute energy efficiency programs will help advance India's energy security and alleviate the local environmental and global warming impact of abandoned energy growth, specifically coal. If improvement is needed in India's energy productivity then a regular and intensive effort is needed by all sectors.

Renewable energy offers a considerable potential for producing electricity. Wind power plants are rapidly expanding of over the last five years, so in that sense renewable energy sector is the fastest growing section amongst all the power generation sources. Along with wind power, solar power plants can also contribute to the removal of electricity shortages, reduction of local pollution and carbon emissions from conventional power plants. Policies that encourage faster growth of wind energy, development of new transmission grids, and ways to combine renewable sources into the grid are being worked on and confidently will be set up soon to speed up wind penetration.

Shukla has concluded in his research paper that the various merits of biomass energy has made the policy makers aware about the future prospects related to biomass due to which conditions are created for it to make inroads into the energy market. Modern biomass has potential to break through in four segments:

- Process heat applications in companies producing biomass waste,
- Cooking energy in household and commercial sectors (through charcoal and briquettes),
- Electricity production and
- Transportation sector by means of liquid fuels.

Various economic reforms have opened the doors for competition in energy and power sectors in India. Biomass energy future lies in its use with modern state of the art technologies. An investigation under competitive dynamics in energy and electric power markets using the Indian-"MARKAL model" (Shukla, 1996; Loulou et al., 1997) has suggested that biomass energy has considerable potential to enter the Indian energy market under strong worldwide greenhouse gas improvement scenarios in future. The future potential of biomass energy depends on providing reliable energy services at viable costs. If biomass energy services can compete on a fair market, then this will happen very soon in India. Policy priorities should be to disseminate biomass energy services towards market and to transform the market towards fair competition. The best option is to utilize the waste material effectively.

If 10,000 MW power has to be generated then potential availability of agro residues and wood processing waste in India is required. However Biomass waste shall be inadequate to support the rising demands for biomass resources. If sustained supply of biomass is required then production of energy crops, wood fuel plantations etc. is required to be done on a large scale. Land contribution, improved biomass productivity, cost-effective operations of plantations and planning the infrastructure are significant areas which shall determine the future of biomass in India.

Heinimö et al (2007) have mentioned in their paper that the markets of biomass for energy are developing very fast and becoming more international. A remarkable increase is there in the use of biomass for energy needs, and there will be plenty of challenges to overcome. The main objective of the study was to clarify the alternative potential scenarios for the international biomass market until the year 2020, and based on the circumstances, to identify essential steps needed towards the critical working and sustainable biomass market for energy and power purposes.

Faaij (2007) have pointed in their publication that Biomass is a multipurpose energy source that can be used for production of heat, power, and transportation fuels, as well as biomaterials and when generated can be used on an enduring basis, it can also make a large input to reducing greenhouse gas (GHG) emissions. In this publication the authors have mentioned the significance of biomass as a bioenergy. A comparison is also done with other fuel options. Biomass is the most important renewable energy option in today's time and will most probably maintain that position during the first half of this century and also beyond that [IPCC, 2007; IEA, 2006a].

For converting solid biomass to power and heat many combined heat and power (CHP), co-firing and various combustion concepts provide trustworthy, efficient, and clean conversion routes. Production and use of biofuels is growing at a very quick pace. Although the future role of bioenergy will depend on its competitiveness with fossil fuels and on agricultural policies globally, it seems realistic to expect that the current contribution of bioenergy of 40-55 EJ per year will increase significantly. A range from 200 to 400 EJ may be expected during this century, making biomass a more important energy supply option than mineral oil today, large enough to supply one third of the world's total energy needs. Bioenergy markets provide major business opportunities, environmental benefits, and rural expansion on a worldwide level. If indeed the global bioenergy market is to develop to a size of 300 EJ over this century (which is quite possible given the findings of recent global potential assessments) the value of that market at E4-8/GJ (considering pre-treated biomass such as pellets up to liquid fuels such as ethanol or syn fuels) amounts to some E1.2 ~ 2.4 trillion per year. Feed stocks can be provided by the residues from agriculture/ forestry, and from the timber industry, biomass produced from degraded and marginal lands, and biomass produced from good quality grazing and agricultural lands without endangering the world's food and feed supply, forests, and biodiversity. The prerequisite to achieve such a situation is that agricultural land-use efficiency is increased, especially in developing countries.

Murtala et al (2012) in their paper have identified in the developing countries some of the major biomass resources and their potentials for a sustainable energy production and utilization. They have highlighted some conversion techniques and channels for the biomass resources as well as the terms of some adequate actions for their proper utilization. The use of biomass as energy source will provide a tremendous opportunity for easing of greenhouse gas emission and reducing global warming through the substitution of conventional fossil-based energy sources.

Anil Kumar et al (2015) have discussed in their paper about biomass energy resource, its potential, energy conversion and policy for promotion as implemented by Government of India .On 31st March 2013 the total installed capacity for electricity generation in India was 2666.64 GW. Out of total generation, 10.5% is contributed by renewable energy, out of which 12.83% power is being produced using biomass. India has excess of agricultural and forest area which includes about 500 million metric tons of biomass availability per year. In India total biomass power generation capacity is 17,500 MW.

At present power being generated is 2665 MW which include 1666 MW by cogeneration. Various categories of biomass in India are also discussed in this paper. Their research reveals that India has huge potential for biomass feed stock from different sources. Government of India has implemented different policies and programs, and also executed various projects for biomass power generation. Such approaches have included the whole biomass energy sector which incorporates the bio gas, bio diesel etc. in the policies. Government of India has focused on the exploitation and development of biomass energy sector with strategic policy and program which is remarkable portion of this review paper.

Bauen and Berndes et al have stated a concise review on various aspects of bioenergy like technical, environmental, economic, social and policy issues in their paper. The paper discusses about the future potential of bioenergy and the main aspects for exploitation of biomass energy in the short and medium term. It also discusses the principal risks and problems associated with the development of bioenergy, and how they may restrict its use. The aim of this paper is to assist policy and other decision makers with information that is beneficial to exploiting the opportunities and reducing the risks associated with bioenergy, and which may help in the sustainable development of the sector.

Daugherty have discussed in their research paper about the efficiency of Biomass Energy Systems which are analyzed through a Life Cycle Assessment. In the paper they have shown that biomass energy growth can meet rising global electricity demand in the midst of international concerns over fossil fuel dependence, global warming, and problems of land use. This study presents a life cycle assessment (LCA) of biomass energy systems to analyze some of the limiting factors. Limiting factors or the constraints such as increased land use, fossil fuel use, and corresponding CO_2 emissions further influence international biomass development efforts. The life cycle assessment evaluated alternative processes that might increase effectiveness. The LCA pointed out that "integrating Salix short-rotation forests, biological fertilizers, and integrated gasification technologies into the biomass energy system would reduce fossil fuel use and CO_2 emissions by 74 percent and land use by roughly 97 percent". By implementing

Salix, biological fertilizer, and gasification technologies biomass energy systems can become much more efficient and competitive for generation of renewable electricity.

Dimpl (2011) have stated in their publication, how small-scale electricity generation from biomass takes place and he has tried to find out how wood or other dry biomass is transformed into a combustible gas and then into electricity via a generator set which is a perfect solution for isolated rural areas where problem of electricity is quite regular, but at country side there is an abundance of shrubs, rice husk, mustard husk and peanut husks straw or other forms of biomass.

The technology, known as biomass gasification, is quite popular, from more than a hundred years now. Continuous rising prices of fossil fuels since 2008 and the debate about climate change, this know-how has again come under consideration as a renewable energy source in villages and remote areas. However, converting biomass to electricity is not an easy task as some manufacturers would like to make us consider. The "Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ)" on behalf of the German Ministry for Economic Cooperation and Development has been looking for sustainable solutions to provide access to vital energy services in villages and has analyzed experiences with small-scale applications of the gasification technology over the last ten years. This analysis was based on publicly available documents, as well as interviews and email discussions with experts in this field. This study refers to small scale applications of less than 100 KW which can be put in through biomass gasification technology and the potential available for providing fundamental energy services to households and people living in remote areas. The biomass gasification technology is a remarkable option for rural development. It promises the following:

- Sustainable change of locally available biomass into electricity for local supplies;

- A local value chain with income generation for the suppliers of the biomass as fuel;

- Incentives for afforestation.

Hence, it will remain on the energy development plan. However, as given above; many problems still remain unsolved, especially for small applications:

- No reliable technology is readily available.
- High costs for technical development, repair and maintenance make it unbeneficial.
- Due to toxic waste hazardous threats to the environment and to health exist.
- Suitable management of such a intricate system and the sustainable provision of appropriate feedstock are needed for all biomass based electrification technologies.

In short, the viability of the technology has been proven and the costs are fairly competitive. Hence, more pilot projects with a certain research component are needed.

Moreira (2005) have stated in their paper about the Global Biomass Energy Potential. He has tried to find out that the rigorous use of renewable energy is one of the options to stabilize CO_2 atmospheric concentration at levels of 350 to 550 ppm. However what is really significant is to quantify the amount of final energy since the use of replenishable sources may involve conversion efficiencies, from primary to final energy, different from the ones of traditional energy sources. In reality, IPCC (Inter governmental Panel on Climate Change) does not provide a complete account of the final energy from renewables, but using several options which are available to moderate climate change, it is possible to stabilize atmospheric carbon dioxide (CO_2) concentration at a low level.

In this paper, the author has evaluated in detail biomass primary and final energy using sugarcane crop as a substitute since it is one of the highest energy density forms of biomass, and through reforestation using a model presented in IPCC Second Assessment Report (SAR). The conclusion is that the primary-energy potential for biomass has been under-evaluated by many authors and by IPCC and this under-evaluation is even more for final energy since sugarcane allows co-production of electricity and liquid fuel. Regarding forests, IPCC results are reproduced for primary energy and calculated final energy. Sugarcane is a tropical crop and cannot be produced in all the land area forecasted for biomass energy plantation in the IPCC/TAR evaluation (i.e. 1280 Mha). However, there are large areas of unexploited land, mainly in Latin America and Africa where the weather is warm and comfortable and good rainfall is there. With the use of 143 Mha of these lands it is possible to produce 164 EJ/yr of main energy using farming productivities.

2.3 Papers related to Biomass Power Generation

Hao & Luo (2012) have put forward some counter measures for the orderly development of China’s biomass power generation in their paper. Some of which are as follows:

- Investigation and real time assessment of the biomass resources.
- Development of mechanism for biomass power generation industry.
- Comfortable environment for investment, and well-coordinated and unified regulation institution.

They have also analysed in their paper how biomass power generation's industry development is taking place over the period in advanced Countries. The key points of which are:

- Development of planning and strategies.
- Policy support and the development of biomass energy market.
- Creation of market of energy industry.
- How to ensure the raw materials supply in a continuous basis.
- Technology research and development.
- Cooperation and competitiveness of the industry, internationally.

In their paper, Constraints in China's Biomass Energy Development have also been discussed which are as follows:

- Lacking of systematic and scientific overall planning.
- Technology research and development ability for biomass power generation.
- Costly generation of power by Biomass.
- Irrelevance of law and government support policy.
- Limited investment and financing channel.
- Unsound market mechanism.
- Undeveloped and insufficient supporting mechanism.
- Uncertain biomass resources distribution.

- Blocked supply channel of raw materials.
- Weak foundation of technology industrialization.
- Market environment not suitable.

Mohan &Partheeban (2012) have tried to point out that use of Biomass is growing globally. Although advancements in biomass energy technologies, mostly bio-energy consumption in India still remains confined to traditional uses. The latest advancement of technologies opens the possibilities to convert biomass into synthetic gaseous or liquid fuels (like ethanol and methanol) and electricity (Johansson et al, 1993). Absence of biomass energy market has been the primary barrier to the penetration of latest biomass technologies. Authors have also studied that transformation in biomass energy in Asia has happened in the last two decades along the following three routes:

- Improvement of technologies in traditional biomass applications for example cooking and rural industries.
- Development of process for conversion of raw biomass to superior fuels (such as liquid fuels, gas and briquettes).
- Deep penetration of biomass based electricity generation technologies.

These developments have opened new avenues for biomass energy in several Asian countries, besides India. China, in early 1980’s, initiated a nationwide program to distribute improved cook stove and biogas technologies. The program led to raising energy efficiency of cook stoves to 20 percent, saving nearly a ton of wood fuel per household (Shuhua et al, 1997). In 1995, nearly 6 million biogas digesters produced 1.5 billion m^3 gases annually (Baofen and Xiangjun, 1997). Another 24,000 biogas purification digesters, with a capacity of 1 million m^3, were in use for treating waste water for 2 million urban populations (Keyun, 1995). Two hundred small biogas based power plants, adding to a capacity of 3.5 MW, produced 3 GWh of electricity annually (Ravindranath and Hall, 1995). Research and development in China has paying attention on a process for converting a high quality Chinese sorghum breed into liquid fuel, pyrolysis technology and gasification of agriculture residue and wood. Lately, Biomass based electricity generation technologies have penetrated in the Chinese market. The policy support brings to a promising future for modern biomass in China. Biomass contributes 44% of the total energy in Philippines; it is a major biomass using nation. First nation to initiate the modern biomass program was Philippines. In 1970's, a three quarters of electricity in Philippines was produced from oil and diesel fired power plants.

In the study by **Liu et al (2014**), a comparative evaluation of 5 typical Biomass power generation (BPG systems) has been conducted through a hybrid life cycle inventory (LCI) approach. They have analyzed that requirements of fossil energy savings, and greenhouse gas (GHG) emission reductions, as well as emission reductions of SO_2 and NOx, can be achieved by the BPG systems. The co firing systems were found to result better than the biomass-only fired system and the biomass gasification systems in terms of energy savings and GHG emission reductions. Comparing with results of conventional process-based LCI, an important point to note is the important contribution of infrastructure, equipment, and maintenance of the plant, which require the input of various types of materials, fuels, services, and the consequent GHG emissions. The results show characteristics and differences of BPG systems and help locate critical opportunities for biomass power development in China.

In the study, the authors **Sun &Guo (2014)** have tried to find out that biomass energy resource is rich in China, and it has the potential for development. However, the distribution of biomass energy resource is scattered, and different regions have different resource reserves. Henan and Shandong provinces are the main distribution regions of biomass energy, and the regional industrial efficiencies are higher than other regions due to the conducive environment of fuel resource market and power grid. Meanwhile, the potential distribution of biomass energy resource is equivalent with that of conventional primary energy source to some extent, which makes the regions with low reserves of primary energy source have great potential for utilizing biomass energy.

In their paper **Kader et al (2012)** have tried to explain that in Bangladesh, the contribution of renewable source in electricity generation is almost negligible. But it has potential sources for electricity generation such as biomass and solar power system. Bangladesh is an agricultural country and has huge biomass resource such as agricultural residue, municipal solid waste, poultry droppings etc. Government support could significantly encourage biomass-fueled electricity and other low carbon energy technologies.

A techno-economic evaluation was done by **Purohit & Chaturvedi** in **2018** where modern bioenergy was recognized as a low-carbon resource by policy-makers around the world to meet climate policy targets. India considers bioenergy as a boon in electricity generation as well as in other applications. In two different forms bioenergy for power generation can be used i.e. pelletized and non-pelletized. For co-firing in coal thermal power plants or biomass power plants the non-pelletized form has been used.

International trade is increasing because of climate policy targets adopted by developed countries & biomass pellets are used on large scale. Estimation of the cost of biomass pellet-based electricity production and assessing its financial viability has been done by the researcher.

Transport and storage costs are minimized, handling is improved, and the volumetric calorific value is increased because of pelletization process. Pelletization may not increase the energy density on a mass basis, but it can increase the energy content of the fuel on a volume basis. Hence, for long-distance transport, it makes sense to transport pellets rather than biomass feedstock only. In terms of agriculture and forestry residues potential of the different states varies. States like Karnataka and Andhra Pradesh have more potential for producing forest and agriculture residue in comparison to Tamil Nadu. On the basis of financial analysis researchers concluded that the cost of electricity production will be higher, based on the import of biomass pellets. With high carbon price or stringent targets for biomass-based electricity generation for states that do not have surplus agricultural/forestry, residue availability can only help.

Zhao & Feng (2014) conducted a research in China where significance of bioenergy was realised. They stated that developing bioenergy is must due to scarcity of fossil fuel resources, reduction in the demand for greenhouse gas and environmental protection. The study throws light on current development situation of biomass power industry in China, discusses the dilemmas of industry's development in a perspective of industry chain and gives recommendations. The research also brings various development strategies on the table along with development objectives, technology roadmap, and the related policy guarantee measures for the biomass power industry. Although, the industry is not market-oriented, the equipment technology is lagging, supply of the raw materials and production equipment are a big constrain but still, the development of biomass power generation industry in China has made considerable progress in terms of investment, installed capacity and on-grid energy, and also made enormous contributions to carbon reduction. It can be concluded that with scientific and technological progress, China's biomass power industry will develop rapidly with reduced cost. From the perspective of government planning, goal of biomass power generation industry is to reach to its installed capacity to 13 million KW in 2015 and 30 million KW in 2020. To ensure stable and fast development, recommendations given above will provide policy support as well as development direction. The appropriate conclusions will be fruitful for reference to the scholars who want to study the biomass power industry development. In order to ensure the accomplishment of the goal government support, development of biomass power generation industry, both in terms of promoting market mechanisms or the electricity price policy, as well as the research and development input, in the future with scientific and technological progress, and economic and social development, China's biomass power industry will expand rapidly, and the cost will be further reduced. There is a promising future for the development of biomass power industry in China.

Gebreegziabher, Oyedun et al (2014) studied the research paper on designing and optimization of biomass power plant & concluded that among the various renewable energy sources, biomass provides some benefits because of its low cost and presumed zero-carbon emission when compared with fossil fuels. The moisture content of biomass is often high that lowers its heating value, reduces the combustion temperature and create operational problems. Due to which, while burning biomass for power generation, biomass is often dried prior to the combustion. While performing it, heat integration studies are performed on to a biomass power plant that burns empty fruit bunches (EFB) as fuel. To identify opportunities of heat integration among the drying and power generation systems & to visualize the intensity, composite curves of all studied cases are plotted. In order to maximize the power output of a biomass power plant or reduce the drying cost, proper heat integration in between the steam power plant and the drying process is required. From this study one can conclude that with proper drying and heat integration, the overall efficiency of a biomass power plant can be improved significantly.

2.4 Literature related to supply chain management of Biomass

A review of the paper authored by **Wu et al (2013**) shows that according to the National Medium and Long-term technology development plan of China (2005-2020), the important development areas of bio energy in China in the coming 10 years are bio power generation, bio gas engineering, bio fuels and solid fuels. In 2020, the total use of bio energy per year will account for 4% of the total energy consumption in China. Due to the characteristics of agricultural biomass use such as variable distribution, seasonal work, and different types of ownership, the collection, storage and transportation of agricultural biomass become the bottlenecks of large-scale utilization of agricultural biomass. Therefore, it is essential to establish a reasonable and efficient agricultural biomass supply chain management system so as to support the sustainable development of bio energy industry.

A Case Study by **Alam, Pulkki, Shahi, et al (2012)** investigates an optimal biomass supply chain for four large-scale biomass-based power plants in Northwestern Ontario. It has been a priority research area recently due to greater emphasis put on green energy sources in Canada FMU's. Power plants can increase their profits from FMUs that are closer to the power plants. However, their profits significantly increase if the power plants offer higher prices. This is possible only if the suppliers maintain the quality standards and lead time requirements of the buyers. The variations in costs and gross margin structures under various model scenarios are explained by location of depletion cells relative to power plants, availability of each type of biomass in depletion cells, biomass demands, and differential processing costs for two types of biomass. This modeling framework may be applied elsewhere to study the similar problem of biomass supply chain. The results of such modeling can help managers make improved decisions relating to biomass supply chains for bioenergy production.

In the dissertation authored by **Chaabane in (2011),** he has pointed out about the Sustainable supply chain management and that it covers interactions between the economic dimension, the environment, and society. In this article, he has presented a generic mathematical model to assist decision makers in designing sustainable supply chains over the entire life cycle. The methodology presented him is general enough and may be applied to other supply chain studies to evaluate their performance in term of cost and carbon emissions.

In the paper, **Sokhansanj et al (2008)** have developed the Integrated Biomass Supply Analysis and Logistics (IBSAL) model to replicate biomass supply chains from the field to the bio refinery. The model simulates the flow of biomass through collection, transport, storage, and preprocessing and estimates energy utilisation and costs. It identifies the potential minor improvements at every step of the supply chain (optimum designs) and critical improvements for the integration of the entire feedstock supply infrastructure (logistics).

The research paper by **Sambra et al** is a part of a continuing project, BioREF (Bio refinery for sustainable Reliable Economical Fuel production from energy crops). BioREF is planned to develop, in an energetic way, a yardstick for future integrated and sustainable bioenergy production systems that will contribute to improve Denmark's position in the biofuel production. The objectives of the work mentioned in this paper are to optimize the harvest and logistics for the movement of oilseed crops and appropriate agricultural residues for production facilities and return the process residues for agricultural use as part of the overall biomass feedstock infrastructure. In this respect, the supply chain is required to comprise of optimized steps of harvesting the crop, collecting residues, storing and transporting.

Vlachos et al (2008) have discussed in their paper about a quantitative analysis based approach, how it is evolved and that it takes into account all major aspects in the design of waste biomass supply chains, developed for energy generation. By this a comprehensive biomass supply chain optimization model is offered for the strategic allocation of its nodes and its related flows. They conclude by developing the application of the planned methodology on a test case study for a biomass supply network for the Region of Central Macedonia, Greece. Logistics and supply chain management have come up as disciplines of utmost importance for the utilization of natural substrates and waste biomass.

Astro logistics Inc have stated in their article the best practices in developing efficient and effective transportation systems within the supply chain some of which are as follows:

- Buy-in throughout the organization; distribute executive-level responsibility; support policies.
- Arrange supply chain goals with business goals.
- Exploit efficiencies; reorganize processes and use automation to handle transactional operations.
- Become a role model; cooperate with suppliers and customers to share benefits. Create close-loop process for reporting and recounting of inventory.
- Establish vital criteria for transportation vendor selection within the supply chain.
- Enhance allotment in a manner so that cost and trips are reduced. Combine and optimize routes to reduce loads.

Rentizelas, Tolis, et al (2009) have shed the light on the rarely investigated issue i.e. the biomass storage problem (esp. because of seasonal availability) and the multi-biomass supply chain. Generally, researchers choose the lowest cost storage method available, ignoring the effects this choice may have on the total system efficiency but here researchers analyzed the three most frequently used biomass storage methods and applied it to a case study to come up with tangible comparative results. Moreover to reduce the storage space requirement they have introduced the innovative concept of combining multiple biomass supply chains and an application of it is also performed for the case study examined. From the case study, it was concluded that the lowest cost storage method indeed constitutes the system-wide most efficient solution, and that the multi-biomass approach is more advantageous when combined with relatively expensive storage methods. Since everything has its own pros & cons this method also do, as this low cost biomass storage method do bear increased health, safety and technological risks.

Allen, Browne et al published a research paper where they addressed the issue of considering logistics costs and the integrated management of logistics activities vital for the success or failure of a product or industry supply chain considerations and costs of using biomass fuel on a large scale for electricity generation at power stations.

The focus of the paper was to examine the options for supplying the end user with biomass fuel of the right measurement in the right quantity at the right time from resources which are characteristically diverse and often seasonally dependent. It is at this scale, the logistics of biomass fuel supply are likely to be both complex and potentially problematic, as logistics costs will have a huge impact on the total delivered cost of biomass (i.e. the total cumulative cost of biomass fuel at the point of delivery to a power station). The study assessed potential supply systems for the supply of fuel to power stations, calculated the delivered costs of these supply chains, and identified the relative advantages of the various systems and the environmental impacts of biomass fuel supply. It concentrated on the supply chain components from the point of harvesting through to delivery at the power station.

Röser (2012) has applied a three-dimensional approach in his paper which investigates the forest energy supply chains from a technical, economic and social viewpoint. Four case studies in different operational environments have been conceded to investigate the applicability of the three dimensional approach to increase operational efficiency.

The literature demonstrates that the chosen approach was practical to find out the complex relationships between the selected technologies and different supply chain elements and stakeholders thereby contributing to maintain or increase operational efficiency of forest energy supply chains. Also, it captures the effect of different aspects and characteristics of the various operational environments on the setup and organization of supply chains. This will be an important knowledge to ensure or improve operational efficiency when adapting existing forest energy supply chains or when building up supply chains in new operational environments.

Windisch, Sikanen et al (2010) investigates how modern supply chain management applications can be increasing the profitability of forest fuel procurement operations. Since profit margins are low, decreasing the provision costs could boost wood-based bioenergy business. The study is based on the investigation of two Finnish forest owners associations (FOA) deals in forest fuel procurement using a modern SCM tool. The investigation is done by cost-benefit analysis (CBA) using the net present value (NPV) methodology to find out the profitability.

The study has proved that supply chain management applications can increase the efficiency and profitability of forestry in the rapid growing field of forest fuel procurement. The results of the cost-benefit analysis are important since they prove that SCM systems can help to increase forest energy business.

Tallaksen (2011) had studied in their paper that establishing a biomass supply chain is rather simple in concept. However, there are more details that must be considered to make the feedstock supply chain work as an efficient system. Since every situation is unique, supply chain forming needs to be based on the conditions for the each facility or market, the biomass will supply. The common elements that apply to developing successful supply chains are that they are using sustainable volumes of bulky biomass and that the biomass is reached to the conversion facility at an economically viable cost. Correct project planning and operations are needed to make sure that these elements are part of any new supply chain and will help to have a successful biomass to energy project.

The aim of the research paper by **Svanberg (2013**) is to explain how principles of supply chain management (SCM) give important conditions for the production, accessibility and use of energy, from the point of origin to the point of consumption. The paper identifies three separate trajectories in which the interplay between SCM and energy can release potential for research and practice.

Energy resources are important to power industrial processes in manufacturing and logistics, while their use is also a main contributor to carbon emissions. The consolidative nature of SCM provides conditions for enhancement in use and accessibility of energy, and can make possible the transition in which fossil fuels are replaced with a system of supply and conversion of renewable energy. These opportunities are highlighted by building a set of three trajectories, which range from a true supply chain perspective on the energy sector, to an up-stream and down-stream perspective.

Nilsson et al (2011) have explored themes and challenges in making supply chains environmentally sustainable. The study starts with a systematic review, and content analysis of articles in top-ranking related journals from logistics, transport, sustainability and environmental areas, and ended with research propositions contributing to the further improvement of supply chain management.

From the systematic review five major areas of challenges for supply chain management are derived as:

- costs,
- complexity,
- operationalisation,
- mindset, cultural changes, and
- uncertainties.

They have concluded that there is a essential need for models and frameworks that take into consideration the complexity involved, take holistic perspectives, and challenge the basic assumptions underlying most of the research published (i.e. reductionism, positivism and economic growth).

Johnson describes woody biomass feedstock supply chains that support the biofuels and utility industries. Following key issues have not been acknowledged or fully addressed:

- Existing forest products industry and allied demand requirements.
- Extended supply chain through many industries adds complication in supplying woody biomass for biofuels through the consumer.
- Resource restrictions associated with many industries demanding the same feedstock (i.e., logs).

- Insecurity in the logging industry.
- Harvesting limitations of federal- and state-owned lands, and
- Additional processing of logs (i.e., chipping and shredding) required by biofuels and utilities industries that is not plentiful in the current supply system.

Additional issues include the transportation infrastructure requirements needed to transport woody-biomass feedstock via truck, rail, barge, or intermodal combination.

Alam, Pulkki et al (2012) have tried to put across the complexities of buying woody biomass feedstock to the Atikokan generating station (AGS) in northwestern Ontario (NWO) in the cost effective way. The paper applies two optimization models to analyze the impacts of biomass competition on cost structures and gross profit margins for four biomass-based power plants in northwestern Ontario. Model scenarios are run to study the impacts of changes in parameters related to biomass type and processing technology, and prices of inputs costs and outputs costs for procurement.

Ji, **Sittibud et al (2017)** have tried to explain that biomass is a biological material derived from living organisms and can be utilised as sources of energy. This paper is concerned about optimizing the biomass supply chain focusing particularly in Loei province, Thailand. A mixed integer linear programming model is used to establish the best possible biomass production and supplier allocation that result in the lowest cost to meet electricity demand.

Mitra, Datta (2013) have done a survey of sustainable supply chain management practices in Indian manufacturing firms. They have developed India-specific items for the survey based on the related literature and feedback from companies. The objects on SSCM practices and firm's achievement may be of use to research scholars and professors, experts as key success factors (KSF) and key performance indicators (KPI), respectively for further reference. In this literature an outline is made related to the scope of adoption of SSCM practices by Indian manufacturing companies. The authors expect that the outcomes of the study would help in the development of a suitable regulatory framework and implementation of SSCM practices to a greater extent in India's search for environmental sustainability.

Niu (2010) have stated in their dissertation the importance of information and technology on the supply chain management. Specifically, the study focuses on the technology circumstances and performance effects of knowledge management by supply chain organizations. Taking the view point of a supply chain dyad, the study first presents a survey research that examines the association between the supply chain's IT capability and knowledge management capacity and the knowledge management capacity's impact on supply chain performance. The outcomes and results indicate that the ability of supply chain firms to jointly manage knowledge resources is an essential requirement of supply chain strategic performance.

Azmi, Hamid, et al (2017) outlines the importance of integration in supply chain management (SCM) by linking the functions of logistics as it applies in strategic business process. Often, business processes are developed at the strategic level but are never identified precisely in logistics or in SCM. Various processes like Customer Service Management (CSM), Demand Management, Supplier Relationship Management (SRM), and Customer Relationship Management (CRM), are not directly connected to logistics or SCM. This paper also identifies the literature that expressed the importance of integration and how business processes can be pertinent in the implementation of key logistics activities in the supply chain context.

Lichocik and Sadowski (2013) have discussed in their paper the problem of supply chain management efficiency in the context of common theoretical considerations pertaining to supply chain management. The authors have also highlighted determinants and realistic implications of supply chain management efficiency in tactical and operational contexts. In this study critical analysis of logistics literature is done, along with free-form of interviews are conducted with top management representatives of a company in the transport service limited (TSL) sector.

Efficiency of supply chains is not only a task for which a logistics department is responsible as it is a strategic decision taken by the management as regards the method of future company's operation. Properly planned and completed logistics tasks may result in improving performance of the industries and companies as well as of the entire supply chain. Fundamental improvements in supply chain efficiency may be ensured by examining theoretical models on the strategic level and implementing a chosen concept.

Agustina et al (2018) have stated in their literature about the design, planning and management of biomass supply chain. According to them biomass energy is one of the most significant renewable energy source apart from solar, wind, hydropower and geothermal, which can replace fossil fuel energy. Over the years, researchers have been exploring the process of producing and converting biomass into bioenergy, but the importance of logistics was observed recently. Efficiency and effectiveness are the important parameters of supply chain management and logistics. This paper presents a literature review of articles published in journal articles from 1992 to2017, which includes the bioenergy production interface and logistical issues and supply chain management.

This review will contribute to researchers and practitioners in understanding the design, planning and management of biomass supply chains by considering detailed modeling analysis. The review also presented the issues and challenges related to biomass supply chain modeling. Many studies focus on bioenergy forests, as many industries that use forest resources already have sufficient infrastructure, networks and process technologies. Based on the rising issues of the broad study, it has identified a need to involve uncertainty and sustainability in the optimization of important systems. In the real world, demand, capacity and cost affect the supply chain complexity to some extent. Aspects related to economy, environment and society will definitely be affected by issues related to sustainability in the near future.

Lautala, Hilliard et al (2015) have stated in their paper the various opportunities and challenges faced during the design and analysis of biomass supply chains, they have tried to explain the main components of biomass supply chains, examples of related simulating applications, and how they address aspects related to environmental metrics and management. This paper introduces a concept of integrated supply systems for long term biomass trade and the factors that influence the bioenergy supply chain landscape, including models that can be used to examine the factors.

The paper also covers various aspects of shipping and transportation logistics, ranging from alternative modal and multi-modal alternatives for the introduction of support tools for transportation analysis. They have carried out an analysis that the biomass supply chain is one of the most critical elements of large-scale bioenergy production and in many cases a key hurdle for procuring initial funding for new developments on specific energy crops. Most of the productions depend on complex transforming chains which are linked to food and supply markets. The term ‘supply chain’ covers several issues ranging from farming and harvesting of the biomass, to treatment, supplying and storage of biomass. After energy conversion, the product must be delivered to final point of consumption, either in the form of heat, electricity or more substantial products, such as pellets and biofuels. Effective supply chains are very important for bioenergy generation, as biomass tends to have challenging seasonal production cycles and low mass, energy and bulk densities.

Petridis, **Arabatzis et al (2018)** have explained in their paper that the design of a biomass supply chain is a big challenge where multiple stakeholders with often differing objectives are involved. To have room for the aspects of the stakeholder, the supply chain design should integrate multiple objectives. In addition to the supply chain design, the management of energy from biomass is a challenging task, as the procedure of generation of biomass products needs to be allied with the rest of the operations of the biomass supply chain. For the optimal design of biomass supply chain a mathematical framework is presented in this paper. An integrated statistical framework, that models biomass generation, transportation and warehousing throughout the terminals of a biomass supply chain is studied in this paper. Owing to inconsistent objectives, weights are imposed on each aspect, and a 0-1 weighted goal programming mixed-integer linear programming (WGP MILP) model is developed and used under environmental, economic and social criteria for all possible weight representations.

The results of the study show that if importance is given to the environmental aspect, expressed with high values in the environmental condition then it considerably reduces the level of CO_2 emissions resulting from the transportation of biomass through the various nodes of the supply chain. Environmental and economic criteria seem to be moving in the same path for high weight values in the equivalent aspect. From the outcomes it is seen that, as compared to environmental and economic criteria, social criterion seems to move in the opposite direction. An integrated mathematical framework is presented modeling biomass production, transportation and warehousing. To the best of the authors' knowledge, such a framework that integrates multiple goals and objectives with supply chain design is yet to be published.

Zamar, Gopaluni et al (2017) have analyzed that the supply chain optimization for biomass-based power plants is an important research area due to greater importance on renewable power energy sources. Deterministic mathematical models help in studying about the biomass supply chain design and operational planning models. While these models are advantageous for making decisions, their applicability to real world problems may be incomplete because they do not take into account all the issues occurring in the supply chain, including uncertainties in the parameters. So through this article a statistically strong quantile based approach for stochastic optimization under uncertainty, is built upon scenario analysis. The authors have applied and evaluated the performance of the approach to address the problem of analyzing competing biomass supply chains subject to random demand and supply. The proposed approach was found to do better than alternative methods in terms of computational efficiency and ability to meet the random problem requirements.

Sharma et al (2013) have discussed in their report the basis, overview, modeling, challenges, and future about biomass supply chain design. They have studied that biofuels are identified as the potential solution for diminishing fossil fuel reserves, increasing oil prices, and providing a clean and replenishable energy source. The major barrier preventing the commercialization of lingo-cellulosic bio refineries is the complex conversion process and their respective supply chain. Efficient supply chain management of a lingo-cellulosic biomass is essential for success of second generation biofuels. This paper analytically describes energy needs, energy targets, biofuel feed stocks, conversion processes, and finally provides a comprehensive review of Biomass Supply Chain (BSC) design and modeling. Specially this paper presents a detailed review of mathematical programming models developed for BSC and identifies key problems and potential opportunities. After reading this review readers will have an idea about biomass feed stocks and biofuel production as well as an idea about complete analysis of the BSC modeling and design.

Akhtari et al (2019 have tried to find out that economic viability is one of the main considerations in bioenergy and biofuel projects and is greatly influenced by uncertainty in biomass availability, cost, and quality, and bioenergy and biofuel demand and prices. One important aspect of decision making under uncertainty is the viewpoint of the decision maker towards risk, which is not taken care of in the biomass supply chain management literature. In this paper, the gap is addressed by evaluating alternative supply chain designs taking into account uncertain future conditions resulting from changes in biomass availability and cost, and bio product and energy prices. Three decision rules, maximax, minimax regret, and maximin, representing, respectively, optimistic, opportunistic, and pessimistic perspectives, are used for evaluation. It is assumed that the decision maker has knowledge about the prospective future events, but the probability of their occurrence is not known. According to the outcomes of the case study, based on optimistic and opportunistic viewpoints, investment in bio energy and biofuel conversion facilities was suggested. Production of both biofuels and bio energy would not be profitable under negative conditions. Therefore, investment in only bio energy facilities was prescribed under negative and pessimistic conditions.

Ulonska and König et al have described in their work about the optimization of multiproduct bio refinery processes with consideration of biomass supply chain management and market developments. The authors have tried to find out that even though a shift from conventional to renewable resources is anticipated, lingo-cellulosic bio refinery concepts still struggle with economic feasibility and sustainability. In order to overcome these barriers, a full analysis from biomass supply chain, process performance development, and product-portfolio assortment is targeted. Addressing the economic viability and sustainability already at an early process development stage when only limited knowledge is available, Process Network Flux Analysis (PNFA) [Ulonska et al., AIChE J.2017,62, 3096–3108] is capable of methodically identifying the most valuable processing pathways. This enables a first performance ranking based on the profit or global warming potential of pathways, thereby accelerating development of the process. The methodology is herein extended to consider biomass supply chain optimization and market-dependent price developments such that all main influencing factors are considered as till only processing networks have been taken care of. The absolute methodology is validated identifying reasonable plant locations in North Rhine-Westphalia, Germany. Enhancing economic viability of the finest performing biofuel ethanol, a multiproduct bio refinery is targeted coproducing value-added chemicals. Herein, a coproduction of iso-butanol raises the profit significantly: a mass ratio of at most 1.9 (ethanol: iso-butanol) is required to break even.

Martins and Carneiro et al have stated in their paper that how the demand for biomass has risen due to increasing needs of de-carbonising energy intensive processes. Biomass production, distribution and use for energy generation involve several supply chain systems of which understanding requires a complete analysis of the biomass supply chain management. The present article gives an idea of the volume and variety of research carried out in the production and management of biomass supply chains for energy production. The authors have critically evaluated that how well studies have captured multifaceted issues related to the supply chain management of biomass used for energy production and identified future research trends in this field. The VOS viewer (Center for Science and Technology Studies, Leiden University, Leiden, The Netherlands) and SciMat (University of Granada, Spain) tools are employed for the construction of scientific maps that exhibit the evolution of research in the biomass supply chain management area for energy production. In America, England and Italy the results discovered that research on the biomass supply chain for power generation is booming. Nevertheless in Brazil, India and China, studies are still at an infant stage. There is increasing concern about the emerging new trends related to biomass supply chain management for energy production, especially if clean energy aims to hold a prominent place in the global energy template.

CHAPTER-3

Research Methodology

3.1 Introduction

Research means search for knowledge. Research methodology is a logical procedure of identifying the research problem, gathering and analyzing data to find out the conclusion and solution to a problem undertaken. This chapter covers the research methodology of this study. It explains the need, importance, objectives and hypothesis of the study. Research methodology states the procedure meant absolutely for the research design as well as for the structure of the said research theme. This tends to highlight more on the research procedure to work effectively. Thereby the idea of the research structure encompasses for the intellectual potential to get some way in to the concept. The idea which considers the research issues as well as the research aims, objectives and research questions. According to Jill Collis and Roger Hussey (2003) for the successful research analysis the researcher has to roll down on the technically approved techniques.

This technique satisfies the research framework which is meant for the proper channelization of the research procedure. Thereby the researcher focuses on the quantitative as well as qualitative data procedures to generate the data analysis. Consequently the study covers sampling techniques, and various tools and techniques used for the purpose of data analysis and interpretation.

3.2 Research Methodology

Research methodology consists of all the methods & techniques applied by the researcher to carry on the research. It is a systematic procedure for solving a problem. Gradually it specifies the flow of research. In essence the procedures by which researchers go about their work of describing, elucidating and predicting phenomena is called research methodology.

The aim of this research is to estimate the cost of procuring biomass feed stock and to examine the loss of calorific value in various stages of supply chain (harvesting, storing, handling and transportation) so that power stations will get biomass fuel of right requirement in the right amount at the right time from resources which are characteristically diverse and are seasonally dependent

3.3 Research design

Research design is an abstract structure with in which research is done. It helps in collection, measurement and investigation of data. Research design is an outline of what researcher will do from writing the assumptions to the final data analysis.

The entire study was done through the combination of qualitative and quantitative approaches. For qualitative analysis interviews of key persons in companies , farmers and traders were conducted. For carrying out quantitative analysis primary data was collected. The research done here is of exploratory and descriptive type. Exploratory research is basically getting more information on the research topic. Exploratory research is an introductory research conducted to increase under-standing of a concept, to elucidate the exact nature of the problem to be solved, or to recognize important variables to be studied. Descriptive research is used to describe characteristics of a population or event being studied. This study has concentrated on the supply chain components from the point of harvesting through to feeding in the boiler at the power station.

Study involved mainly structured questions which were predetermined and looked-for large number of respondents. Structured Surveys uses formal lists of questions asked of all respondents in the same way. Questionnaire designed was a close ended questionnaire with multiple choices & scaled questions. Closed ended questions include all possible answers/prewritten response groups, and respondents are asked to select among them.

3.4 Objectives of the Study

Research objectives must be clear, succinct and as a declarative statement. The objectives of research study must be in a state to summarize that what is to be achieved from the study. Based on the scope of the research, following objectives were formulated. These objectives are:

1 To ascertain the extent of economic viability of using biomass feed stocks with respect to fossil fuels for the power producers.

2 To illustrate how procurement mix of existing biomass feed stock reduces overall power generation costs and assures regular availability of feed stocks.

3 To evaluate the loss of GCV of Mustard husk biomass feedstock during various stages of Supply Chain Management.

4 To evaluate different transportation configurations which involve middle men (stockiest, contractors and transporters, etc) that will add value in the existing supply chain.

3.5 Research Hypothesis

After conducting the literature review, recognition of research gap and setting of research objectives, research hypotheses had been developed. To fulfill the research objectives, following hypotheses were formulated and tested using suitable statistical techniques:

1 **H_0: There is no significant difference in cost of biomass procured by companies for power generation using different mixes of fuel.**

H_1: There is a significant difference in cost of biomass procured by companies for power generation using different mixes of fuel.

2 **H_0: There is no significant difference in GCV loss of biomass procured by companies for power generation using different mixes of fuel.**

H_1: There is a significant difference in GCV loss of biomass procured by companies for power generation using different mixes of fuel.

3 **H_0: There is no significant association between Supply chain stake holders and mode of transportation of biomass**

H_1: There is a significant association between Supply chain stake holders and mode of transportation of biomass

3.6 Research Variables

- **Procurement cost of Biomass**

For procuring the biomass the companies take the help of the middlemen and the farmers. The middlemen collect the biomass from the farmers and supply it to the power generating units. It is the cost incurred by the companies in procuring biomass from the source to the point where it is put to use. The procurement cost of biomass is less as compared to that of coal.

Procurement cost = Cost incurred to purchase biomass (Rs per MT)

- **Handling cost of Mix**

This is the cost incurred in handling biomass in the organization after it has been supplied by the middlemen or the farmers i.e. to handle it from the yards to the boiler area. As biomass is a bulky and voluminous material its handling cost is high as compared to coal.

Handling cost = Cost incurred in handling biomass from yard to the boiler area (Rs per MT)

- **Total procurement cost**

The total procurement cost is the sum of procurement cost and the handling cost of biomass.

- **Transportation cost**

It is the cost incurred by the company in transporting biomass from the source to the place of power generation.

- **Storage cost**

The average storage cost is the cost incurred by the middlemen in storing the biomass at his place after collecting it from the fields through the farmers or at his own.

- **Last year quantity of Biomass trading (in MT)**

It is the amount of biomass supplied by the middlemen to the company in a year.

- **Ash content as residual of Fuel Mix**

Ash content is the waste left out after biomass or coal is burnt to generate electricity.

- **Biomass mix ratio**

This ratio shows the combination in the feedstock i.e. the amount of coal and the amount of biomass used in the mix which is fed into the boiler.

- **Boiler efficiency**

It is a rate at which the boiler runs efficiently. In short, 80-88% is the generated heating value after the fuel is burnt by the boiler; the remaining of 12-20% is loss. Loss may be due to radiating loss from boiler's adjacent wall, or due to incomplete combustion of the fuel.

- **Thermal unit efficiency**

It is the ratio of output of heat energy to the input. So, for a boiler that produces 210 kW (or 700,000 BTU/h) output for each 300 kW (or 1,000,000 BTU/h) heat-equivalent input, its thermal efficiency is 210/300 = 0.70, or 70%. This means that 30% of the energy is lost to the environment. The thermal efficiency is a dimensionless performance measure of a device that uses thermal energy**.**

- **Power generated due to biomass with respect to total power generation in the plant**

It is the amount of power generated due to biomass in the respect of total power generation in the plant.

- **Gross calorific value of the mix**

It is the heat produced by burning a unit quantity of a solid or liquid fuel at a constant volume. The gross calorific value of coal is higher than that of biomass i.e. on burning coal we get higher amount of heat energy as compared to biomass.

- **Cost per 1000 KCal energy using Mix (Rs) of fuel mix**

The cost absorbed by the companies in generating 1000kcal of energy using the various mixes of biomass and coal**.**

Cost of energy = Total Procurement cost of fuel / GCV of Fuel

- **<u>Type of loss of GCV during storage</u>**

Loss of GCV during storage may be due to biomass blown away with the wind, Moisture addition in biomass, or may be due to adulteration of biomass with sand.

- **<u>GCV loss (%) of Fuel Mix</u>**

This is the loss in % in the gross calorific value of the fuel mix. There is a loss in GCV of the fuel mix while storing and supplying it from the farmer to the companies.

3.7 Data

Primary data is collected through structured and planned questionnaire consisting of close ended questions. Primary data is information gathered specially for the research purpose. It is often gathered after the researcher has gained an insight into the issue by assessing secondary research i.e. through Review of Literature.

Secondary Data is collected from published journals, literatures and reference books, newspapers, magazines as well as reports published in science direct journals, MNRE annual reports, biomass assessment study reports, Bioenergy India magazine etc

Qualitative data is collected through interviews conducted of key persons of companies, selected traders and farmers. The qualitative analysis was done using interview method. In this, interview schedules were prepared for three stakeholders namely employees, traders and farmers. We had an interaction with the business heads of nine companies and a detailed discussion with them regarding their strategies, future prospects, problems and advantages of the use of biomass for power generation.

We had conversation with the selected middlemen regarding logistics problems in the business of biomass, the merits and demerits they find in this business and other troubles that come in their way while supplying this fuel from the farmers to the power producers. We had interacted with some of the farmers also. With their limitations in literacy levels, they were not able to define our requirement up to the expectations. So we succeeded in having a small interview with them regarding the advantages and disadvantages in selling the biomass husk to the middlemen or to the power producers.

3.8 Research Tool Design

The questionnaire method was used for primary data collection. The questionnaire is designed in a manner grouping questions in accordance with the objectives of research. Besides questionnaire other methods like interviews were also adopted to enhance the progress of data collection through questionnaire and to observe closely the hidden and unexplored aspects related to the objectives of the study.

Questionnaire was designed in two stages:

Stage 1: A rough draft was framed keeping in mind factors extracted from quantitative research and by reviewing questionnaires from the research papers and journals.

Stage 2: The rough draft of questionnaire was discussed and reviewed with the industry experts, renewable energy consultants and statisticians. Questionnaire was designed and sent to industry experts, certain questions were removed and some were added as per their advice. The final framework of questionnaire was designed as per the recommendation of the experts and statisticians.

3.9 Sampling Methodology

1 Employees

Total 12 companies were there having different business models which were using biomass as a feed stock for power generation in Kota region. Out of these 12 companies only 9 companies responded. In our survey we found respondents covering procurement, quality, technical/ engineering and costing departments having approximately 250 employees. We tried to contact 125 employees (50% of total population) and successfully 141 employees responded. All visits to the companies were arranged by their respective HR departments. It was not an easy task to survey the employees of private/ public organizations as the matter is confidential in terms of strategies and figures. The list is given below.

Table 3.1

List of Companies

S No.	Company Name
1	DCM Shriram Ltd.
2	ShriramRayons Ltd
3	Kalpataru Power
4	Surya Chambal Power Ltd.
5	Orient Green Power Ltd.
6	Goyal Proteins Ltd.
7	Ruchi Soya Industries Ltd.
8	Shiv Edibles Ltd.
9	S.M. Environmental Technologies Pvt. Ltd.

2 Traders

The information regarding the traders who are involved in the supply chain management of biomass was gathered through the companies. In total 38 traders/middlemen responded us and shared their business model as well as the difficulties faced by them. Purposive sampling was done to select the traders.

3.10 Statistical Methods & Tools

Mainly One way ANOVA and Chi square tests were applied for carrying out the analysis and for testing the hypothesis.

One way ANOVA

An ANOVA test is a way to find out if survey or experiment results are significant. In other words, they help to figure out if there is a need to reject the null hypothesis or accept the alternate hypothesis. Basically, in it groups are tested to see if there's a difference between them. The analysis of variance frequently referred to as the ANOVA is a statistical technique particularly designed to test whether the means of more than two quantitative populations are equal. This technique was developed by, R. A. Fisher in 1920s and is capable of productive application to a diversity of practical problems. Basically, in this classifying and cross classifying of statistical results is done and then they are tested to see whether the means of a specified classification differ considerably or not. In this way it is determined whether the given classification is significant in affecting the results.

Chi-Square Test,

It is written as $\chi 2$ test, is a statistical hypothesis test that is valid to perform when the test statistic is chi-square distributed under the null hypothesis, specially Pearson's chi-square test and variants thereof. Pearson's chi-square test is used to find out whether there is a statistically significant difference between the expected frequencies and the observed frequencies in one or more groups of a contingency table.

For analysis MS Excel and SPSS 22.0 trial version were used for analysis.

3.11 Significance of Research

Through this research we are trying to estimate the cost of procuring biomass feed stock and also trying to analyse the loss of calorific value in various stages of supply chain (harvesting, storing, handling and transportation) so that power stations will get biomass fuel of right measurement in the right amount at the right time from resources which are very diverse and are seasonally dependent.

Very few research studies have been done in this area especially in Kota region. So this study will definitely help the present power generating companies and the upcoming companies with regard to the type of mix (biomass and coal) they should use in the form of feedstock for generation of power. Distributed generation of power is possible using biomass based electric power generation technologies. The large scale dispersion of biomass power technologies depends on their delivered cost and consistency in direct competition with conventional electricity sources in centralized electricity supply. In India, the principal competing source for electricity supply is the coal based power. Associated with conventional electric power plants are some negative social and environmental issues. All through the coal and nuclear fuel cycles, there are significant environmental and social damages. On the contrarily, biomass energy cost is highly variable, depending upon the source, location etc and it also offers positive environmental and social benefits. Biomass plantation is often a best way to recover degraded lands and to generate considerable employment.

3.12 Research Problem and Research Gap

This study aims at filling the existing research gap in an emerging potential energy scenario. Review of literature suggests that many studies have been done in the areas related to biomass energy, biomass power generation and supply chain management of biomass but very few or no studies have been done in the areas related to the procurement cost of using biomass fuel, logistics and the means of supplying and transporting biomass from the farmers end to the power generating end of the companies.

This study begins with analyzing the stakeholders (employees, traders and farmers) of the various power producing companies, who are using biomass as a feedstock for power generation in Kota. The research work becomes more relevant in this region as it addresses the supply chain considerations and the costs and benefits of procuring biomass fuel on large scale for electricity generation at power stations. It is at this extent of use that the logistics of biomass fuel supply is likely to be both intricate and potentially challenging and logistic costs will have an important impact on the total delivered cost of biomass. It is important to recognize that logistics costs and integrated management of logistics activities play an important role to the success or failure of a power station.

3.13 Limitations

- In order to make the study more precise, specified and objective oriented, this research has been confined to the Kota region. Data analysis is done for the middlemen, employees and transporters attached to the selected power producers of Kota region. Sample drawn from the selected region shall not be applicable to any other part of country as supply chain is very specific to location and product handled.

- Very large data sampling was not possible as there are only few companies in Kota region who are into this business of generating power using biomass.

- Not possible to collect data from the farmers as they are not willing to respond and tell much about themselves.

- Due to competition in procurement of biomass companies are not publishing and declaring statistics and data and they are not willing to disclose their procurement strategies also.

- Secondary data was not available to a larger extent as very less periodicals and magazines are available.

CHAPTER-4

Interpretation

and

Analysis of Data

4.1 **Introduction:**

The purpose of the chapter is to highlight the outcomes of the study, resulted by the application of analytical and statistical tools for testing the hypothesis. A wide variety of researches related to biomass studies provides a good combination of theoretical and practical insight into various proportions of this developing necessity-based energy industry.

Data Analysis and Interpretation is a process of assigning a meaning to the information gathered from the Data source (primary and secondary) and to draw conclusions out of them. Data Analysis can be of two types qualitative and quantitative. In this research both quantitative and qualitative data analysis is done.

A. QUANTITATIVE DATA ANALYSIS

4.2 General Profile:

In quantitative data analysis primary data was collected using questionnaires. Primary data is information gathered specially for the research purpose. It is often gathered after the researcher has gained an insight into the issue by assessing secondary research i.e. through Review of Literature. The parameters of general profile are –the prominent hardship in business, types of traders, locality of traders, total power generation capacity of thermal unit, types of boilers and type of boilers * type of mix.

4.2.1 The prominent hardship in business of biomass

Various problems are being faced by the people who are involved in the business of biomass. The major problems are fire, rains, problem of transporting, overloading, chances of accident if trolleys are overloaded with the biomass husk. As can be seen in the table 4.1, 47.4% suppliers say that theft, rains, overloading and fire are the main problems faced by the people involved in the supply chain of biomass.

Table 4.1 The prominent hardship in business of biomass

Type of Hardship in business	Frequency	Percent
Fire, rain and transportation, overloading, accident, stacking and covering	16	42.1
Rains, Fire, Theft, Road transportation	4	10.5
Theft, rains, overload, fire	18	47.4
Total	38	100.0

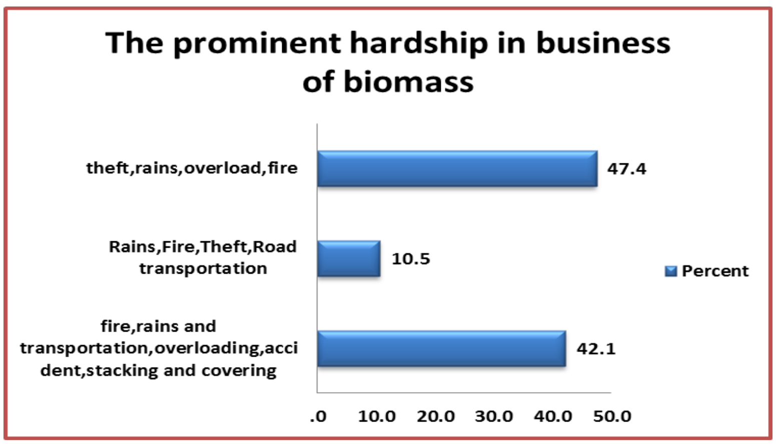

Figure 4.1 The prominent hardship in business of biomass

4.2.2 Types of traders

Mainly two types of traders are involved in the biomass business i.e. organized and individual. The traders in organized sector are those whose employment terms are fixed and regular, and the employees get assured work. In individual employment terms are not fixed and not assured, 68.4% traders are organized and 31.6% are individual.

Table 4.2 Type of Biomass traders

Type of trader	Frequency	Percent
Individual	12	31.6
Organized	26	68.4
Total	38	100.0

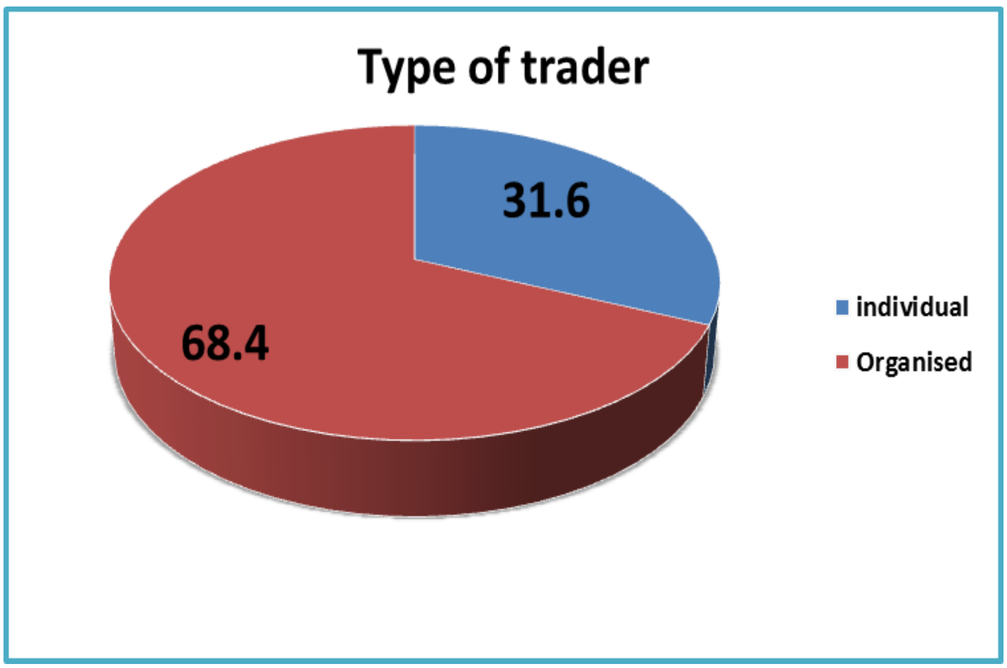

Figure 4.2 Type of Biomass Traders

4.2.3 Locality of traders

Traders are categorized as rural and urban. Rural traders are those living in rural areas i.e. nearby villages. They are having friendly contacts with the farmers in the villages and so can be of good help to the power producing plants for supplying the biomass husk through the farmers. Urban traders are those living in cities and the nearby areas.

Table 4.3 Locality of Biomass trader

Locality of trader	Frequency	Percent
Rural	20	52.6
Urban	18	47.4
Total	38	100.0

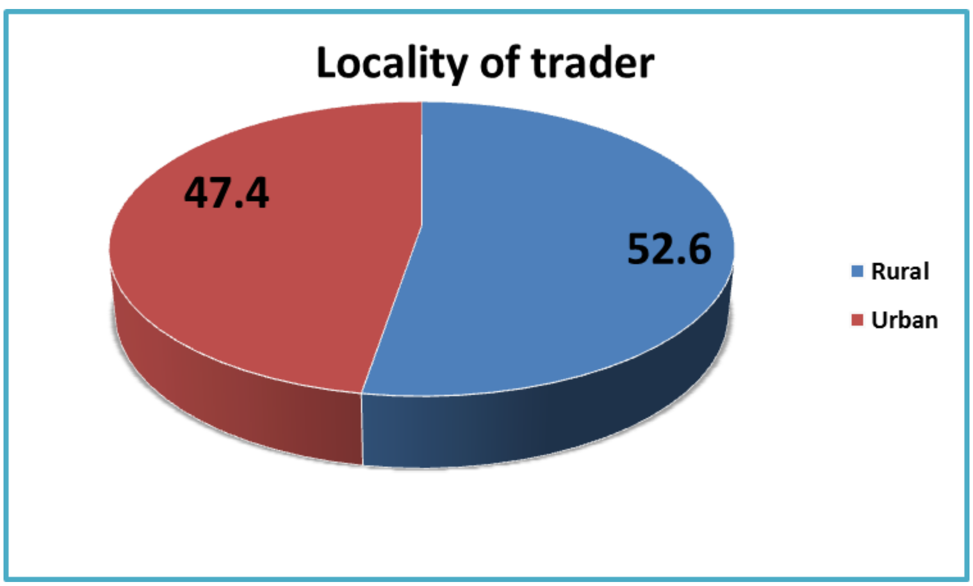

Figure 4.3 Locality of Biomass Traders

4.2.4 Total power generation capacity of thermal unit

The total power generation capacity of thermal unit is from 6-50 MW for most of the companies

Table 4.4 Total power generation capacity of thermal unit

Total power generation capacity of thermal unit		
	No.	%
6 – 50 MW	141	100.0

4.2.5 Type of Boiler

All the companies are using different types of boilers for utilization of different types of feed stocks. Stoker fired boilers are used by 77.3% of people, Pressurized Fluidized bed boilers are used by 12.1%, 10.6% people are using Bubbling fluidized bed boilers. Mostly Stoker fired boilers are used as these types of boilers can be operated efficiently on a variety of fuels namely rice husks, biomass, bagasse, wood, coal, etc. and/or with supplementary fuels such as oil gas. The combustion efficiency for this system is far better than the normal firing system.

In fluidized bed boilers, quick mixing ensures uniformity of temperature. The main advantage of fluidized bed combustion system is that biomass, agricultural waste, municipal waste, plant sludge, and other high moisture fuels can be used for heat generation.

In Pressurized Fluidized bed boilers, the combustion machine and hot gas cyclones are all enclosed in a pressure vessel. Coal has to be fed across the pressure vessel, and similar provision for ash removal is there.

Table 4.5 Type of Boilers

Type of boiler		
Type	No.	%
Stoker fired	109	77.3
Fluidized bed boilers	17	12.1
Bubbling fluidized bed boilers	15	10.6
Total	141	100.0

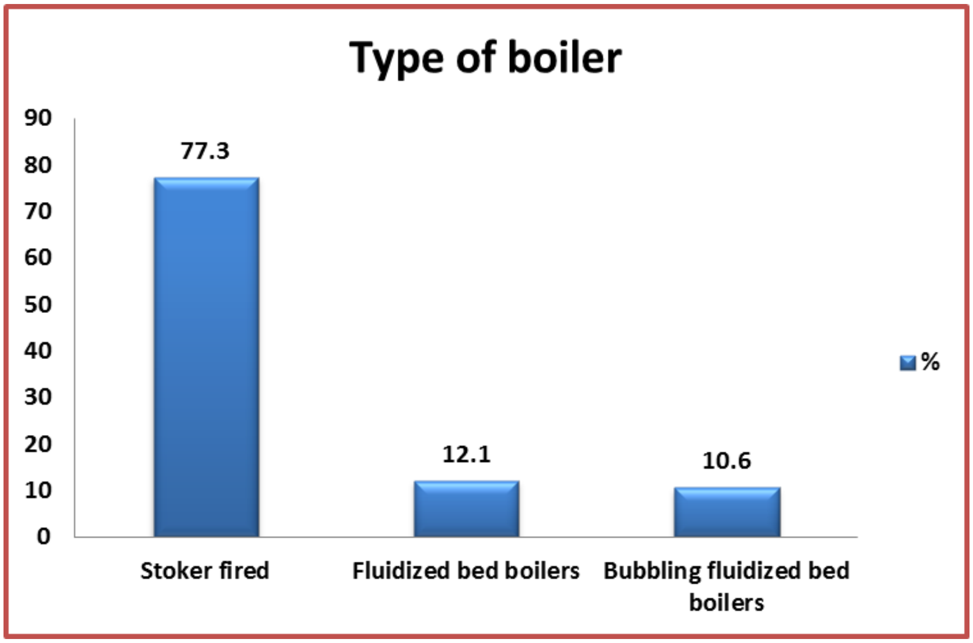

Figure 4.4 Type of Boilers

4.2.6 Type of boiler *Type of mix

The type of Boiler is selected according to the type of mix. When the mix is of Biomass only type the boiler used is stoker fired boiler (85.6%). When coal major mix is used then Pressurized Fluidized bed boilers are mostly used (71.4%).

Table 4.6 Type of boiler * Type of mix

Type of boiler * Type of mix						
			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Type of boiler	Stoker fired	Count	89	16	4	109
		% within Type of mix	85.6%	69.6%	28.6%	77.3%
	Pressurized Fluidized bed boilers	Count	0	7	10	17
		% within Type of mix	0.0%	30.4%	71.4%	12.1%
	Bubbling fluidized bed boilers	Count	15	0	0	15
		% within Type of mix	14.4%	0.0%	0.0%	10.6%
Total		Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0%	100.0%

4.3 OBJECTIVE 1:

To ascertain the extent of economic viability of using biomass feed stocks with respect to fossil fuels for the power producers.

To illustrate how procurement mix of existing and new feedstock reduces overall procurement costs and secures availability. How optimization of biomass procurement supply chain using multiple feed stocks will increase profit margins of power producing plants. Since Biomass is available at lower cost, economics is to be compared with coal having higher cost. To illustrate this objective we have used four parameters namely Availability, Procurement, Consumption & Residual Disposal**.**

4.3.1 Availability

Biomass of mustard crop is available mostly in the months when mustard is harvested i.e. in the months of March-May. Mustard is a Rabi crop so after its harvesting season its waste is utilized for energy generating purposes. Lowest availability of biomass is from August-October, as can be seen below in table-4.7. Biomass is made available to the power generating companies through the farmers or through the middle-men.

Table 4.7 Availability of Biomass in months

Sample Size - Traders (38)			
Availability	Months	Frequency	Percent
Highest availability month of Biomass	March - April	20	52.6
	April - May	18	47.4
Lowest availability month of Biomass	August &September	28	73.7
	September &October	10	26.3

4.3.1.1 Challenges faced by the power generating companies

Various challenges are being faced by the power generating companies to make the biomass regularly available. 78% employees say that due to heavy rains, if the crop is damaged then it leads to heavy loss to the crop in the fields and then in turn it leads to the damage to the biomass. 67.4% employees are of the opinion that entry of new consumer in the nearby area is a big hurdle for them and for 63.8% employees demand supply gap is a very big challenge. Various challenges are depicted in Table 4.8 below:

Table 4.8 Challenges faced by the companies

Sample Size - Employees (141)			
Factor	Options	Yes	Percent
Challenges faced by the companies	Heavy rains leading to crop damage	110	78.0
	Entry of new consumer of biomass in the region	95	67.4
	Demand supply gap	90	63.8
	Drought	89	63.1
	All of the above	56	39.7

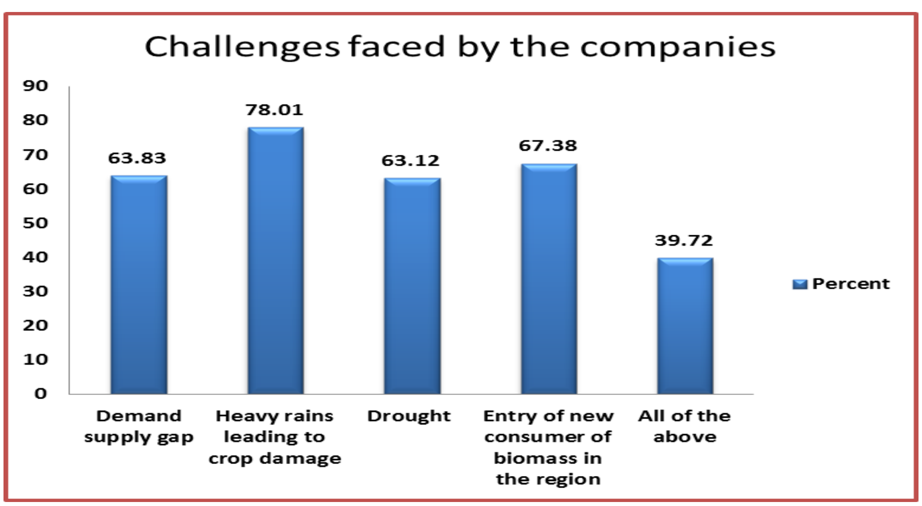

Figure 4.5 Challenges faced by the companies

4.3.1.2 Strategies adopted by the power generating companies for increasing the power generation through Biomass

For procuring the biomass various strategies are adopted by the employees of the power generating companies as can be seen in the Table 4.9, 66.7% employees have subcontracted the procurement activity by developing middlemen in the supply chain. 59.6% people are increasing the in-house storage capacity within the plant. 58.2% employees monitor the rates of the market to wait for the favorable price of biomass in the region and 58.2% have developed storage areas in the nearby regions.

Table 4.9 Strategies adopted by the power generating companies

Sample Size - Employees (141)			
Factor	Options	Yes	Percent
Strategies adopted by the power generating companies for increasing the power generation through Biomass	Sub-contracting of procurement activity by developing middle men in supply chain management	94	66.7
	Increasing the in-house storage capacity within the plant.	84	59.6
	Market monitoring of rates to wait for the favourable price of biomass in the region	82	58.2
	Development of storage area in the region	82	58.2
	Maximize the procurement from nearest source to cater the high demand supply gap	81	57.4
	Development of alternate ways of storing the biomass	75	53.2

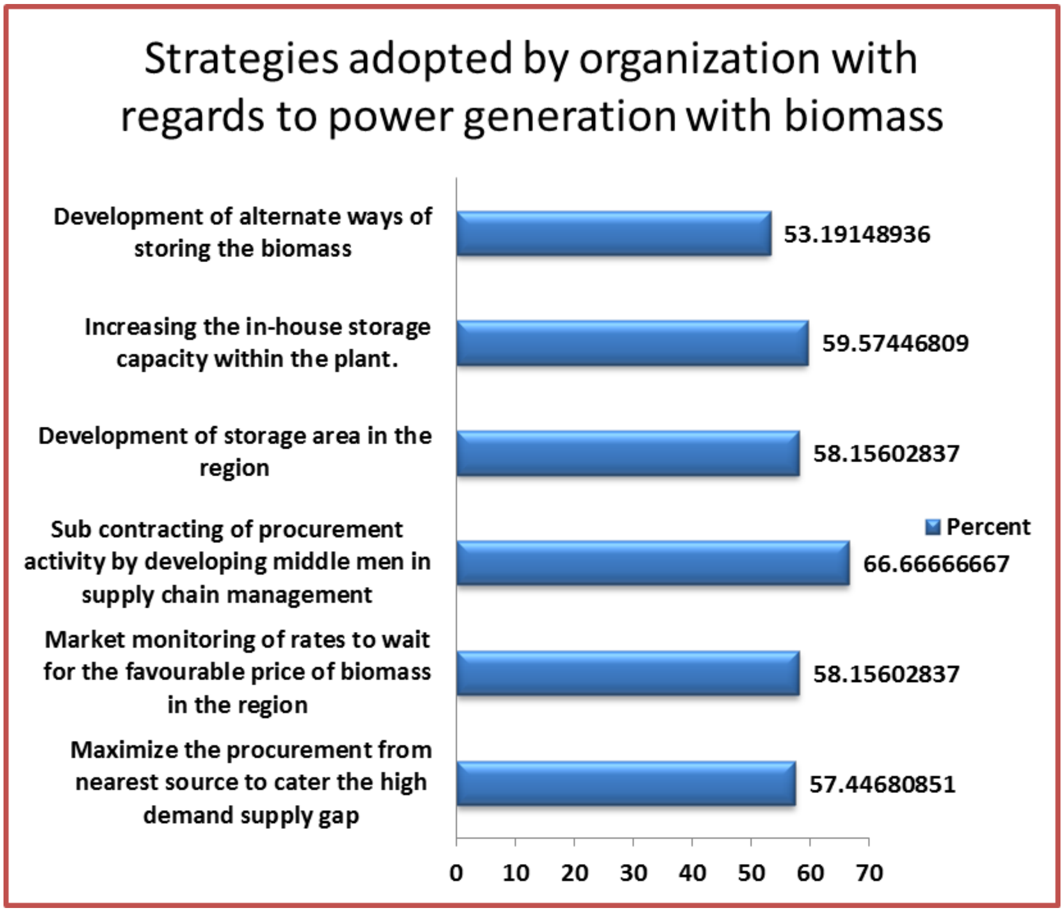

Figure 4.6 Strategies adopted by the power generating companies

4.3.1.3 Biomass vendors

Biomass is mainly made available to the power generating companies by the farmers and the middlemen. Analysis was done for finding out the relationship between the types of biomass vendors and the type of fuel mix.

H_{01}: There is no significant association between types of biomass vendors and the type of mix.

H_{11}: There is a significant association between types of biomass vendors and the type of mix.

52.9% of employees who are using Biomass only are procuring biomass by the middlemen. 78.3% of employees who are using Biomass major mix are mainly procuring the mix by the stockiest and 85.7% of employees who are using coal major mix are mainly procuring the mix by the stockiest as can be seen in the table 4.10. The P value of chi square test is less than 0.05 and there is a significant association between the types of biomass vendors and the types of mix therefore rejecting the null hypothesis.

Table 4.10 Types of Biomass vendors and Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Types of Biomass vendors	Stockiest	Count	14	18	12	44
		% within Type of mix	13.5%	78.3%	85.7%	31.2%
	Middlemen or Agent	Count	55	5	2	62
		% within Type of mix	52.9%	21.7%	14.3%	44.0%
	Farmer	Count	35	0	0	35
		% within Type of mix	33.7%	0.0%	0.0%	24.8%
Total		Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0 %	100.0 %
Pearson Chi-Square			Value	Df	P value	
			59.865	4	0.000	
Inference: Null Hypothesis Rejected						

4.3.2 <u>Procurement</u>

For procuring the biomass the companies take the help of the middlemen and the farmers. The middlemen collect the biomass from the farmers and supply it to the power generating units. The procurement cost of biomass is less as compared to that of coal.

4.3.2.1 Procurement cost of Biomass

H_{02}: There is no significant difference among mean procurement costs of biomass in different fuel mix.

H_{12}: There is significant difference among mean procurement costs of biomass in different fuel mix.

As can be seen in table 4.11 the mean value of procurement cost of biomass in biomass only (mix) is 2391.12 Rs., in biomass major mix is 2670 Rs. and in coal major mix is 2756.57 Rs which shows that there is a significant association between procurement cost of biomass in different fuel mix and the ANOVA P value is less than 0.05, hence rejecting the null hypothesis.

Table 4.11 Comparison of Procurement cost of biomass - Fuel mix

Fuel Mix	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Biomass only	104	2391.12	388.489	38.095	2000.00	3400.00	12.765	0.000	Rejected
Biomass Major Mix	23	2670.00	186.895	49.950	2345.00	3000.00			
Coal Major Mix	14	2756.57	175.958	36.690	2345.00	3000.00			
Total	141	2478.42	375.750	31.644	2000.00	3400.00			

Table 4.12 Multiple Comparisons of Procurement cost of Biomass

Multiple Comparisons					
Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	P value
Procurement cost of biomass	Biomass only	Biomass Major Mix	-365.450	80.110	.000
	Biomass only	Coal Major Mix	-278.885	98.975	.015
	Biomass Major Mix	Coal Major Mix	86.565	117.852	.743

4.3.2.2 Handling cost of Biomass

This is the cost incurred in handling biomass in the organization after it has been supplied by the middlemen or the farmers i.e. to handle it from the yards to the boiler area. As biomass is a bulky and voluminous material its handling cost is high as compared to coal.

H_{03}: There is no significant difference among mean handling costs of biomass in different fuel mix.

H_{13}: There is significant difference among mean handling costs of biomass in different fuel mix.

As can be seen in the table 4.13 the mean value of handling cost of biomass from storage area to boiler feed is maximum in case of Biomass only i.e. 251.96 and least in case of coal major mix i.e. 202.86 which shows that there is a significant association between handling cost of biomass from storage area to boiler feed and the fuel mix. The P value is less than 0.05 hence rejecting the null hypothesis.

Table 4.13 Comparison of Handling cost of biomass from storage area to boiler feed - Fuel mix

Fuel Mix	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Biomass only	104	251.96	42.231	8.806	150.00	300.00	15.503	0.000	Rejected
Biomass Major Mix	23	205.57	21.436	5.729	150.00	250.00			
Coal Major Mix	14	202.86	39.294	3.853	142.00	300.00			
Total	141	211.13	42.269	3.560	142.00	300.00			

Table 4.14 Multiple Comparisons of Handling cost of Biomass

Multiple Comparisons					
Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	P value
Handling cost of biomass from storage area to boiler feed	Biomass only	Biomass Major Mix	-49.101	8.865	0.000
	Biomass only	Coal Major Mix	-2.716	10.952	0.967
	Biomass Major Mix	Coal Major Mix	46.385	13.041	0.001

4.3.2.3 Total procurement cost

The total procurement cost is the sum of procurement cost and the handling cost of biomass. The procurement cost of biomass is 2000 (minimum value) and 3400(maximum value) and the mean value is 2478 as shown in table 4.15. Handling cost of biomass from storage area to boiler feed is 142 (minimum value) and maximum value is 300 (maximum value) and 211 is the mean value .Adding the two costs gives us the total procurement cost.

H_{04}: There is no significant difference among mean total procurement costs of biomass in different fuel mix.

H_{14}: There is significant difference among mean total procurement costs of biomass in different fuel mix.

The total procurement cost is Maximum (mean value) in case of coal major mix (3447.16) and lowest in case of employees using Biomass only (2593.97) as shown in table 4.16. This shows that there is a close association between total procurement cost per MT of mix and the fuel mix. As P value is less than 0.05. Therefore Null hypothesis is rejected.

Table 4.15 Total Procurement cost

Descriptive Statistics - Employees (141)				
	Minimum	Maximum	Mean	SD
Procurement cost of biomass	2000	3400	2478.42	375.750
Handling cost of biomass from storage area to boiler feed	142	300	211.13	42.269
Total Procurement cost	2185.00	3641.00	2689.55	398.845

Table 4.16 Comparison of Total Procurement Cost per MT of mix - Fuel mix

Fuel Mix	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Biomass only	104	2593.97	409.482	40.153	2185.00	3641.00	41.281	0.000	Rejected
Biomass Major Mix	23	3037.59	178.144	37.146	2629.92	3290.30			
Coal Major Mix	14	3447.16	250.511	66.952	3003.50	3761.00			
Total	141	2751.05	463.087	38.999	2185.00	3761.00			

Table 4.17 Multiple Comparisons of Total Procurement Cost per MT of mix

Multiple Comparisons					
Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	P value
Total Procurement Cost per MT of mix	Biomass only	Biomass Major Mix	-443.614	85.012	0.000
	Biomass only	Coal Major Mix	-853.188	105.032	0.000
	Biomass Major Mix	Coal Major Mix	-409.574	125.064	0.004

4.3.2.4 Transportation cost

It is the cost incurred by the company in transporting biomass from the source to the place of power generation.

H_{05}: There is no significant difference among mean transportation costs of biomass in different fuel mix.

H_{15}: There is significant difference among mean transportation costs of biomass in different fuel mix.

The transportation cost's mean value is maximum in case of middle men(1.34) as indicated in table 4.18 and less in case of stockiest(1.08) which shows that there is a significant association between average transportation cost of Biomass per Km per MT (in Rs.) and the supplier. As P value is less than 0.05 hence null hypothesis is rejected.

Table 4.18 Comparison of Average transportation cost of Biomass / Km / MT (in Rs.) – Supplier

Supplier	N	Mean	Std. Deviation	Std. Error	Min	Max	ANOVA F	ANOVA P value	Inference of Null Hypothesis
Stockiest	18	1.08	0.094	0.022	1.00	1.20	10.781	0.000	Rejected
Middlemen or Agent	10	1.34	0.196	0.062	1.00	1.50			
Farmer	10	1.16	0.158	0.050	1.00	1.40			
Total	38	1.17	0.177	0.029	1.00	1.50			

Table 4.19 Multiple Comparisons of Average transportation cost of Biomass / Km / MT (in Rs.)

Multiple Comparisons					
Dependent Variable	(I) Role in Biomass supply chain	(J) Role in Biomass supply chain	Mean Difference (I-J)	Std. Error	P value
Average transportation cost of Biomass per Km per MT (in Rs.)	Stockiest	Middlemen or Agent	-0.262	0.057	0.000
	Stockiest	Farmer	0.180	0.064	0.022
	Middlemen or Agent	Stockiest	0.262	0.057	0.000

4.3.2.5 Storage cost

The average storage cost is the cost incurred by the middlemen in storing the biomass at his place after collecting it from the fields through the farmers or at his own.

H_{06}: There is no significant difference among mean storage costs of biomass in different fuel mix.

H_{16}: There is significant difference among mean storage costs of biomass in different fuel mix.

As can be seen from the table 4.20 that average storage cost of biomass with respect to stockiest is 1444.44 (mean value) that of middlemen is 1531.00 and that of farmer is 1510.00. There is no significant difference among mean storage costs of biomass in different fuel mix and the ANOVA P value is more than 0.05 hence accepting the null hypothesis.

Table 4.20 Comparison of Average storage cost of Biomass (in Rs.) – Supplier

Comparison of Average storage cost of Biomass(in Rs.) – Supplier									
Supplier	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Stockiest	18	1444.44	119.913	28.264	1200.00	1600.00	2.526	0.094	Accepted
Middlemen or Agent	10	1531.00	98.002	30.991	1400.00	1650.00			
Farmer	10	1510.00	84.327	26.667	1400.00	1600.00			
Total	38	1484.47	110.513	17.928	1200.00	1650.00			

Table 4.21 Multiple Comparisons of Average storage cost of Biomass (in Rs.)

Multiple Comparisons					
Dependent Variable	(I) Role in Biomass supply chain	(J) Role in Biomass supply chain	Mean Difference (I-J)	Std. Error	P value
Average storage cost of Biomass (in Rs.)	Stockiest	Middlemen or Agent	-86.556	41.893	0.112
	Stockiest	Farmer	21.000	47.502	0.898
	Middlemen or Agent	Stockiest	86.556	41.893	0.112

4.3.3 <u>Consumption</u>

It is the amount of Biomass consumed by the various power generating organizations.

H_{07}: There is no significant difference among mean consumption of biomass in different fuel mix.

H_{17}: There is significant difference among mean consumption of biomass in different fuel mix.

As can be seen in the table 4.22 the mean value of last year consumption of Biomass in different fuel mix is, 50026.87 MT in biomass major mix, 49150.68 in Biomass only mix which shows that there is a significant association between the last year consumption of biomass and the type of fuel mix. The p value is less than 0.05 hence rejecting the null hypothesis.

Table 4.22 Last year consumption of Biomass (in MT) - Fuel Mix

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Biomass only	104	49150.68	20464.244	2006.684	23000.00	80000.00	8.628	0.000	Rejected
Biomass Major Mix	23	50026.87	19190.272	4001.448	23000.00	64915.00			
Coal Major Mix	14	26656.14	6963.311	1861.023	23000.00	50000.00			
Total	141	47060.11	20415.779	1719.319	23000.00	80000.00			

Table 4.23 Last year consumption of Biomass (in MT)

Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	P value
Last year consumption of Biomass (in MT)	Biomass only	Biomass Major Mix	-876.187	4467.120	0.979
	Biomass only	Coal Major Mix	22494.540	5519.080	0.000
	Biomass Major Mix	Coal Major Mix	23370.727	6571.724	0.001

4.3.3.1 Last year quantity of Biomass trading (in MT)

It is the amount of biomass supplied by the middlemen to the company in a year.

H_{08}: There is no significant difference among mean quantity of biomass been supplied by the middleman in last year to the companies using different fuel mix.

H_{18}: There is significant difference among mean quantity of biomass been supplied by the middleman in last year to the companies using different fuel mix.

As can be seen in the table 4.24 mean value of last year quantity of Biomass trading (in MT) as done by the middle men is 35049.00 and as done by farmer is 26000.00 which shows that there is a significant association between the quantity of trading and the supplier. The p value is less than 0.05 hence rejecting the null hypothesis.

Table 4.24 Comparison of Last year quantity of Biomass trading (in MT) - Supplier

Comparison of Last year quantity of Biomass trading (in MT) - Supplier									
Supplier	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	F	P value	Inference of Null Hypothesis
Stockiest	18	32000.00	8838.419	2083.235	18000.00	50000.00	4.099	0.025	Rejected
Middlemen or Agent	10	35049.00	5774.427	1826.034	25000.00	40000.00			
Farmer	10	26000.00	4807.402	1520.234	23000.00	35000.00			
Total	38	31223.42	7826.054	1269.554	18000.00	50000.00			

Table 4.25 Multiple Comparisons of Last year quantity of Biomass trading (in MT)

Multiple Comparisons					
Dependent Variable	(I) Role in Biomass supply chain	(J) Role in Biomass supply chain	Mean Difference (I-J)	Std. Error	P value
Last year quantity of Biomass trading (in MT)	Stockiest	Middlemen or Agent	-3049.000	2856.646	0.540
	Stockiest	Farmer	6000.000	2856.646	0.104
	Middlemen or Agent	Farmer	9049.000	3239.132	0.022

4.3.4 Residual Disposal

Residual disposal is the waste left out after Biomass or coal is used as a feedstock to generate electricity. The amount of ash content in coal is very high as compared to Biomass.

H_{09}: There is no significance difference among mean ash content as residual of Fuel Mix

H_{19}: There is significance difference among mean ash content as residual of Fuel Mix

As depicted in table 4.26 that the mean value of ash content of Coal major mix is 30.46% and of Biomass major mix is 9.60% and of biomass only is 8.17% which shows that coal has more of ash content. So it shows that there is a close association between ash content as residual of fuel mix. The ANOVA P value is less than 0.05. Hence rejecting the null hypothesis.

Table 4.26 Ash content of mix (%) - Fuel Mix

Ash content of mix (%) - Fuel Mix									
Fuel Mix	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA		Inference of Null Hypothesis
							F	P value	
Biomass only	104	8.17	3.704	0.772	5.13	13.40	294.096	0.000	Rejected
Biomass Major Mix	23	9.60	3.155	0.309	4.35	13.50			
Coal Major Mix	14	30.46	0.362	0.097	29.80	30.80			
Total	141	11.44	7.068	0.595	4.35	30.80			

Table 4.27 Multiple Comparisons of Ash content of mix (%)

Multiple Comparisons					
Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	P value
Ash content of mix (%)	Biomass only	Biomass Major Mix	1.425	0.715	0.118
	Biomass only	Coal Major Mix	-20.864	0.883	0.000
	Biomass Major Mix	Coal Major Mix	-22.289	1.052	0.000

4.4 OBJECTIVE 2:

To illustrate how procurement mix of existing biomass feed stock reduces overall power generation costs and assures regular availability of feed stocks.

To optimize the mixing ratio of biomass with coal as a feedstock and to find out whether the low gross calorific value and low cost biomass is more beneficial to the companies as compared to the high cost coal having high gross calorific value.

To illustrate this objective certain factors are taken into consideration

1) Biomass mix ratio
2) Technical engineering difficulties
3) Engineering changes done in the plant to facilitate the use of biomass
4) Boiler efficiency
5) Thermal unit efficiency
6) Power generated due to biomass with respect to total power generation in the plant
7) Gross calorific value
8) Cost per 1000 KCal energy

4.4.1 Biomass mix ratio

This ratio shows the combination in the feedstock i.e. the amount of coal and the amount of biomass used in the mix which is feeded into the boiler. As can be seen in the table 4.28 that 104 employees are using 0% coal and 100% Biomass (Biomass only), 23 employees are using majorly biomass and very less coal (Biomass major mix) and Only 14 employees are using around 93-94% coal and 6-7% biomass (Coal major),

Table 4.28 Biomass mix ratio (Coal: Biomass) in the boiler fuel

Coal, Biomass	Name of Mix	No.	%
0,100	Biomass only	104	73.8
3,97	Biomass major	9	6.4
4,96	Biomass major	4	2.8
6,94	Biomass major	5	3.5
7,93	Biomass major	5	3.5
93,7	Coal major	6	4.3
94,6	Coal major	8	5.7
Total		141	100.0

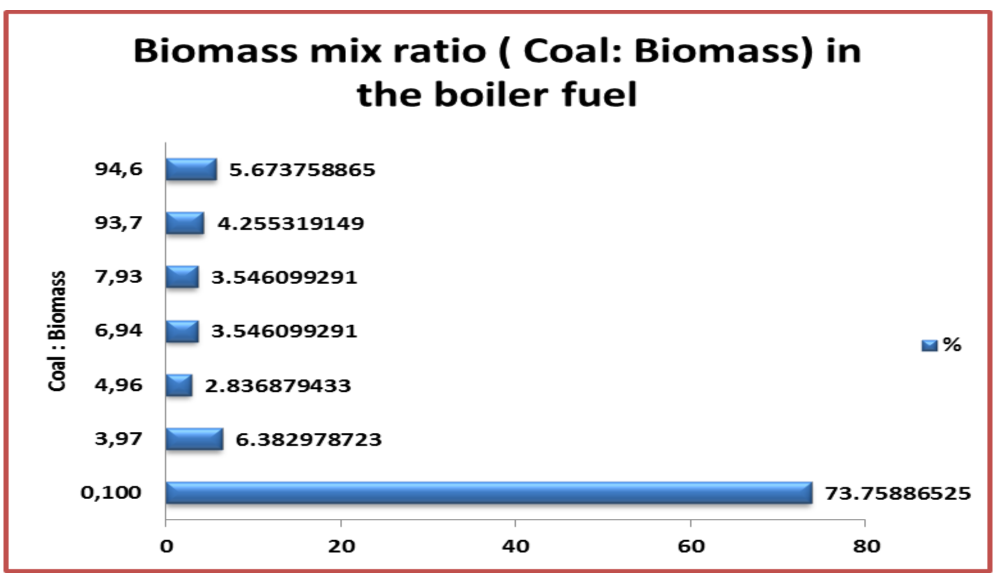

Figure 4.7 Biomass mix ratio (Coal: Biomass) in the boiler fuel

4.4.2 <u>Technical and engineering difficulties faced by the power generating companies</u>

For making the biomass available various technical and engineering difficulties are faced by the companies. These are depicted in table-4.29. 66% employees are of the opinion that Biomass is prone to catch fire, if left in open especially in the hot summer days. 65.2% employees are pointing out that large storage area is needed due to very low bulk density of Biomass. 63.1% employees feel that there are deposits in super heater area of the boiler which create problems for the employees.

Table 4.29 Technical / engineering difficulties faced in using biomass

Factor	Options	Yes	Percent
Technical / engineering difficulties faced in using biomass	Prone to catch fire	93	66.0
	Large storage area due to very low bulk density	92	65.2
	Deposits in super heater area	89	63.1

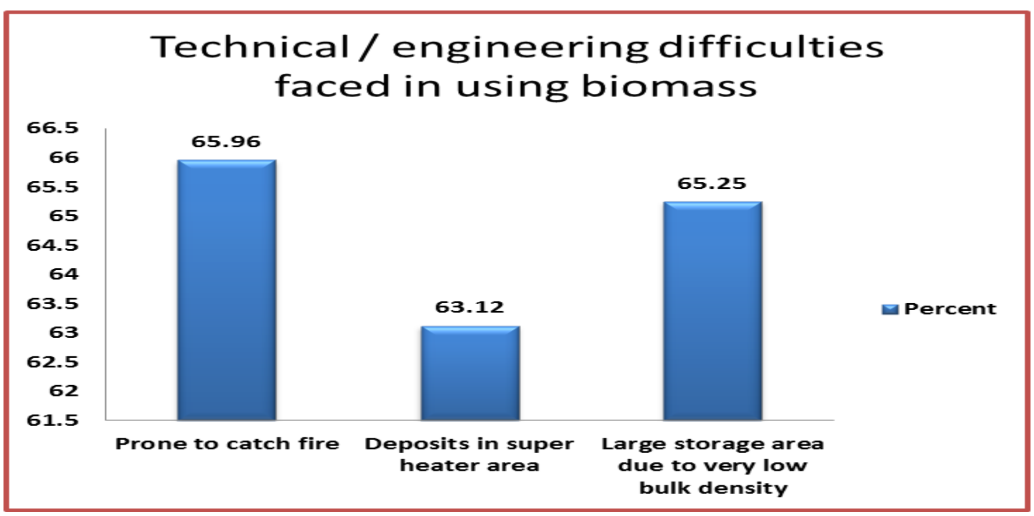

Figure 4.8 Technical / engineering difficulties faced in using biomass

4.4.3 Engineering changes done in the plant to facilitate the use of biomass

Many engineering and technical changes are done by the plant to aid in the use of biomass. 58.9% employees use additional infrastructure to feed the biomass in the boiler. Modification is done in the boiler area by 55.3% employees, this is done mostly by those companies who are previously using coal or any other fossil fuel and then switching over to Biomass. Resizing of steam control unit is done by 44.7% employees as can be seen in table 4.30

Table 4.30 Engineering changes done in the plant to facilitate the use of biomass

Factor	Options	Yes	Percent
Engineering changes done in the plant to facilitate the use of biomass	Additional infrastructure to feed the biomass in the boiler	83	58.9
	Modification in boiler area	78	55.3
	Resizing of steam control unit	63	44.7

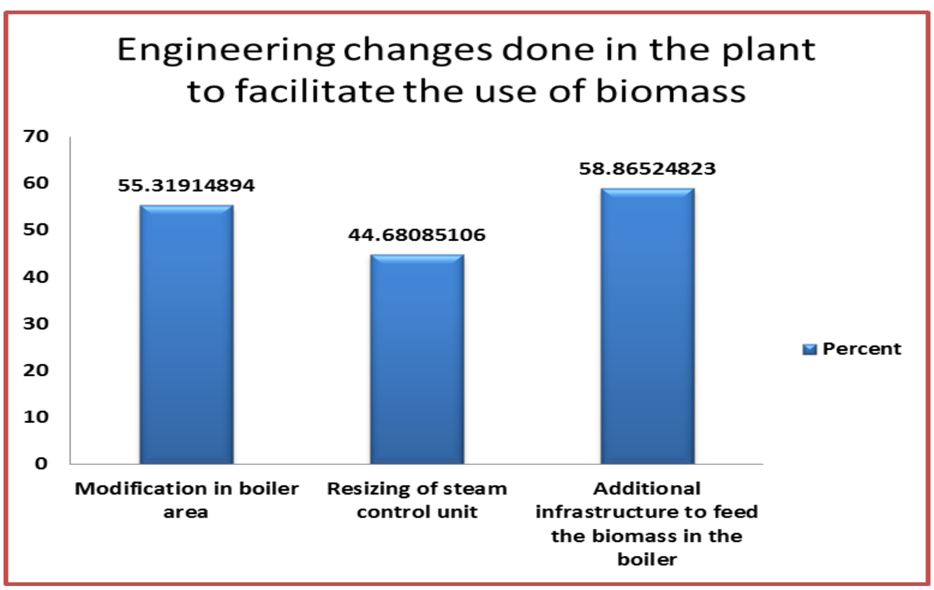

Figure 4.9 Engineering changes done in the plant to facilitate the use of biomass

4.4.4 Boiler efficiency

Boiler efficiency is a measure of how effectively chemical energy in fuel is converted into heat energy in steam which is supplied to the turbines. In order to calculate boiler efficiency, total energy output of a boiler is divided by total energy input given to the boiler, multiplied by hundred.

H_{010}: There is no significant association between boiler efficiency and type of fuel mix

H_{110}: There is significant association between boiler efficiency and type of fuel mix

In the table 4.31 below boiler efficiency is in the range of 70-80% when 76.9% of the employees are those who are using Biomass only mix. The efficiency is between 80-90% when 92.9% employees are those who are using coal major mix. The Pearson chi square value is less than 0.05 and there is significant association between boiler efficiency and the type of mix the null hypothesis is therefore rejected.

Table 4.31 Boiler efficiency * Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Boiler efficiency	Below 70.0 %	Count	5	0	0	5
		% within Type of mix	4.8%	0.0%	0.0%	3.5%
	70.1 – 80.0 %	Count	80	14	1	95
		% within Type of mix	76.9%	60.9%	7.1%	67.4%
	80.1 – 90.0 %	Count	19	9	13	41
		% within Type of mix	18.3%	39.1%	92.9%	29.1%
Total		Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			35.432	4	.000	

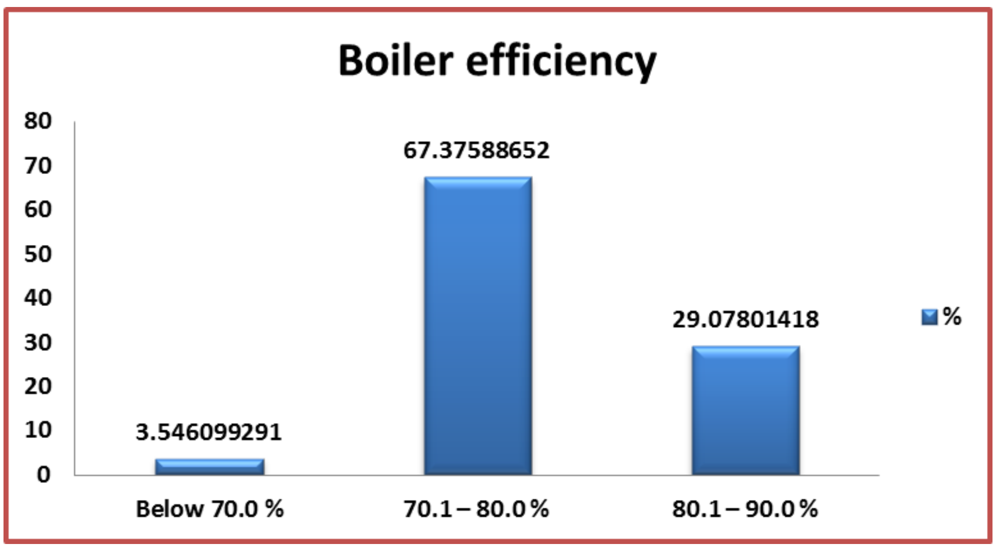

Figure 4.10 Boiler efficiency * Type of mix

4.4.5 Thermal unit efficiency

The thermal efficiency of a boiler is the effectiveness of the heat exchanger of the boiler which transfers the heat energy from fireside to water side. Thermal efficiency is badly affected by the formation of scales or soot on the boiler tubes.

H_{011}: There is no significant association between Thermal unit efficiency and type of fuel mix

H_{111}: There is significant association between Thermal unit efficiency and type of fuel mix

As can be seen from the table 4.32 the thermal unit efficiency is between 25-30% when 50% employees are those who are using Biomass only mix, and 39% employees are those who are using biomass major mix The thermal unit efficiency is above 45% when the users are majorly biomass ones.

The Pearson chi square value is less than 0.05. Hence the null hypothesis is rejected. This shows that there is a significant association between thermal unit efficiency and the types of mixes.

Table 4.32 Thermal unit efficiency * Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Thermal unit efficiency	25.1 – 30.0 %	Count	52	9	14	75
		% within Type of mix	50.0%	39.1%	100.0%	53.2%
	30.1 – 40.0 %	Count	39	14	0	53
		% within Type of mix	37.5%	60.9%	0.0%	37.6%
	Above 45.0 %	Count	13	0	0	13
		% within Type of mix	12.5%	0.0%	0.0%	9.2%
Total		Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	Df	Asymp. Sig. (2-sided)	
			20.025	4	.000	

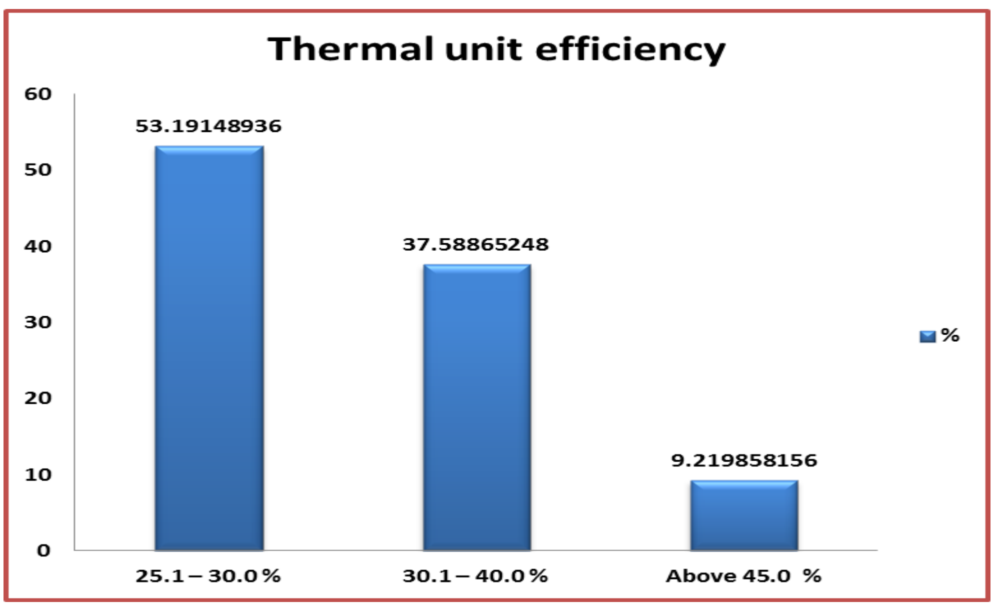

Figure 4.11 Thermal unit efficiency * Type of mix

4.4.6 Power generated due to biomass with respect to total power generation in the plant

H_{012}: There is no significant association between Power generated due to biomass and type of fuel mix

H_{112}: There is significant association between Power generated due to biomass and type of fuel mix

According to this table 4.33 Maximum power is generated (81-100%) by Biomass only i.e. when companies are using more of biomass (76%) at that time maximum power is generated. When majorly coal mix is being used i.e. 78.6% at that time only 6-10% power is generated. The Pearson chi square value is less than 0.05 which shows that there is a significant association between power generated due to biomass with respect to total power generation in the plant and the type of mix. Therefore rejecting the null hypothesis.

Table 4.33 Power generated due to biomass with respect to total power generation in the plant * Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Power generated due to biomass with respect to total power generation in the plant	6 – 10%	Count	0	11	11	22
		% within Type of mix	0.0%	47.8%	78.6%	15.6%
	51 – 80%	Count	25	10	2	37
		% within Type of mix	24.0%	43.5%	14.3%	26.2%
	81 – 100%	Count	79	2	1	82
		% within Type of mix	76.0%	8.7%	7.1%	58.2%
Total		Count	104	23	14	141
		% within Type of mix	100.0 %	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	Df	Asymp. Sig. (2-sided)	
			92.278	4	.000	

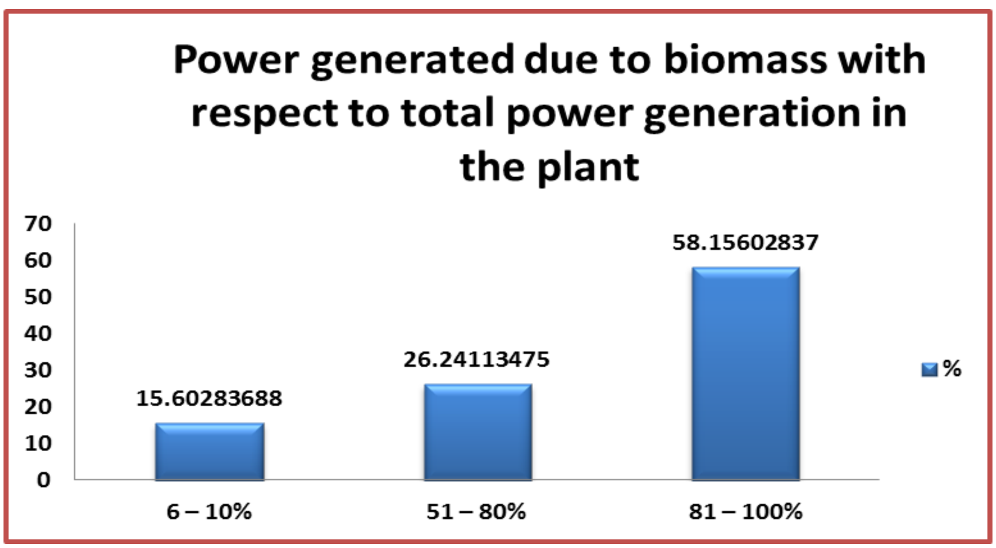

Figure 4.12 Power generated due to biomass with respect to total power generation in the plant * Type of mix

4.4.7 Gross calorific value of the mix

It is the heat produced by combustion of unit quantity of a solid or liquid fuel when burnt at a constant volume. The Gross calorific value of coal is higher than that of biomass i.e. on burning coal we get higher amount of heat energy as compared to biomass.

H_{013}: There is no significance difference among mean gross calorific value of fuel mix

H_{113}: There is significance difference among mean gross calorific value of fuel mix

The mean value of GCV of coal mix (4280.17) is the highest among all the three mixes as can be seen in the table 4.34 whereas the GCV of biomass only (3142.28) and biomass major (3183.61) is less. The ANOVA P value is less than 0.05 which shows that there is a close association between GCV of mix and types of mixes. Therefore null hypothesis is rejected.

Table 4.34 Descriptives of GCV of mix (Kcal/Kg)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
GCV of mix (Kcal/Kg)	Biomass only	104	3142.288	360.668	35.366	3072.1474	3212.4295	2100.0	3667.0
	Biomass Major Mix	23	3183.610	116.281	24.246	3133.3263	3233.8937	3018.0	3427.0
	Coal Major Mix	14	4280.179	186.262	49.780	4172.6344	4387.7241	3823.0	4424.1
	Total	141	3262.011	465.159	39.173	3184.5628	3339.4591	2100.0	4424.1

Table 4.35 ANOVA Tool for GCV of mix (Kcal/Kg)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
GCV of mix (Kcal/Kg)	Between Groups	16145390.265	2	8072695.133	78.747	0.000
	Within Groups	14146920.846	138	102513.919		
	Total	30292311.112	140			

Table 4.36 Multiple Comparisons of GCV of mix (Kcal/Kg)

Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
GCV of mix (Kcal/Kg)	Biomass only	Biomass Major Mix	-41.321	73.775	.841	-216.1160	133.4729
	Biomass only	Coal Major Mix	-1137.890	91.148	.000	-1353.8475	-921.9341
	Biomass Major Mix	Coal Major Mix	-1096.569	108.533	.000	-1353.7150	-839.4235

4.4.8 Cost per 1000 Kcal energy using Mix (Rs.) of fuel mix

In this parameter we are trying to analyze the cost absorbed by the companies in generating 1000KCal of energy using the various mixes of biomass and coal**.**

H_{014}: There is no significance difference among mean Cost per 1000 Kcal energy using Mix (Rs.) of Fuel Mix

H_{114}: There is significance difference among mean Cost per 1000 Kcal energy using Mix (Rs.) of Fuel Mix

Cost of coal major mix is (0.8081), of biomass only mix is (0.8539) and of biomass major mix is (0.9558) as can be seen in the table 4.37 below. This shows that there is no significant association of the cost used to generate 1000 KCal of energy with the mixes. The ANOVA P value is more than 0.05. Hence the null hypothesis is accepted.

Table 4.37 Descriptives of Cost per 1000 Kcal energy using Mix (Rs)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Cost per 1000 Kcal energy using Mix (Rs)	Biomass only	104	.8539	.266	.026	.802	.906	.63	1.66
	Biomass Major Mix	23	.9558	.072	.015	.924	.987	.79	1.07
	Coal Major Mix	14	.8081	.084	.022	.760	.856	.68	.98
	Total	141	.8660	.235	.020	.827	.905	.63	1.66

Table 4.38 ANOVA Tool for Cost per 1000 Kcal energy using Mix (Rs)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Cost per 1000 Kcal energy using Mix (Rs)	Between Groups	.248	2	.124	2.289	.105
	Within Groups	7.471	138	.054		
	Total	7.719	140			

Table 4.39 Multiple Comparisons of Cost per 1000 Kcal energy using Mix (Rs)

Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Cost per 1000 Kcal energy using Mix (Rs)	Biomass only	Biomass Major Mix	-.101932	.053612	.142	-.22895	.02509
	Biomass only	Coal Major Mix	.045823	.066238	.769	-.11111	.20276
	Biomass Major Mix	Coal Major Mix	.147755	.078871	.150	-.03911	.33462

4.5 OBJECTIVE 3:

To evaluate the loss of GCV of Mustard husk biomass feedstock during various stages of Supply Chain Management.

At every stage of supply chain management i.e. starting from the farmers to the power producing companies there is a loss of GCV in the biomass husk, as we store biomass for a longer time its heat generating capacity is reduced to certain extent approx 1%. It is due to many reasons.

To illustrate this objective certain factors are taken into consideration

Type of loss of GCV during storage, Type of loss of GCV during storage * Type of mix Type of loss of GCV during storage * Types of Biomass vendors, GCV loss (%):-

4.5.1 Type of loss of GCV during storage

While looking at the table 4.40 it is seen that during storage biomass can be blown away with the wind and during the rainy season addition of moisture is there into it as biomass has to be left in open. It is also adulterated with sand and stone pieces etc. As biomass gets mixed with these foreign particles its heat producing capacity gets reduced and hence the GCV is lost. Coal has a high calorific value and adulteration of coal is less as compared to biomass so less heat loss is there in case of coal.

Table 4.40 Type of loss of GCV during storage

	No.	%
Biomass blown away with the wind	46	32.6
Moisture addition in biomass	62	44.0
Adulteration of biomass with sand	33	23.4
Total	141	100.0

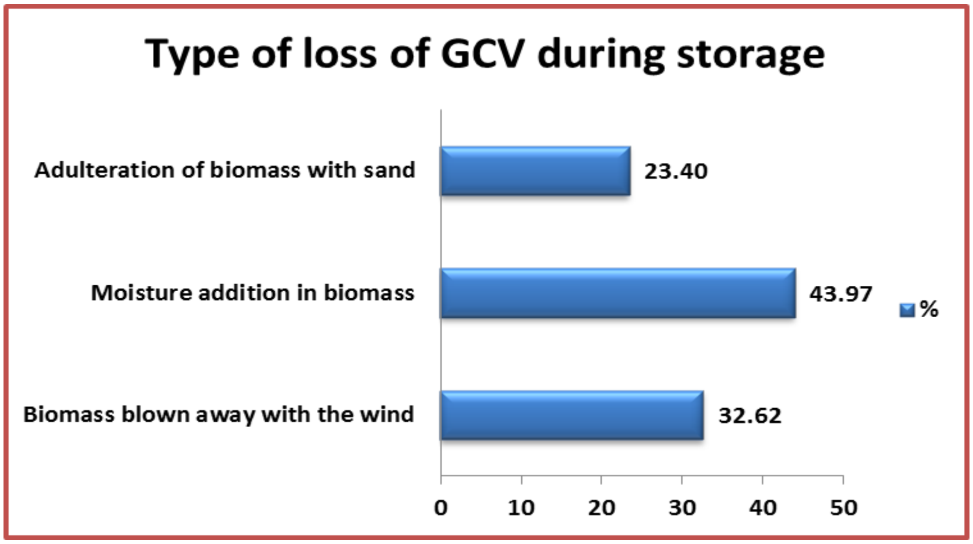

Figure 4.13 Type of loss of GCV during storage

4.5.2 <u>Type of loss of GCV during storage * Type of mix</u>

H_{015}: There is no significant association between Type of loss of GCV during storage and Type of mix

H_{115}: There is significant association between Type of loss of GCV during storage and Type of mix

If we look at the table 4.41 below it is observed that maximum biomass is blown away with the wind when mix is of biomass only type (44.2%). Maximum moisture addition is done in the biomass when the mix is biomass major mix (52.2%) and biomass only (40.4%). Adulteration of biomass with sand is done maximum when the mix is biomass major mix or biomass only type. This shows that there is significant association between type of loss of GCV during storage and the type of mix. The Chi square value is less than 0.05. Therefore, rejecting the null hypothesis.

Table 4.41 Type of loss of GCV during storage * Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
Type of loss of GCV during storage	Biomass blown away with the wind	Count	46	0	0	46
		% within Type of mix	44.2%	0.0%	0.0%	32.6%
	Moisture addition in biomass	Count	42	12	8	62
		% within Type of mix	40.4%	52.2%	57.1%	44.0%
	Adulteration of biomass with sand	Count	16	11	6	33
		% within Type of mix	15.4%	47.8%	42.9%	23.4%
	Total	Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			28.557	4	.000	

4.5.3 Type of loss of GCV during storage * Types of Biomass vendors

As can be seen in the table 4.42 that maximum biomass is blown away with wind when the vendors are the farmers. Maximum moisture addition is done in biomass when the vendor is the stockiest. Maximum adulteration of biomass with sand is done when the vendors are the middlemen

H_{016}: There is no significant association between Type of loss of GCV during storage and Types of Biomass vendors

H_{116}: There is significant association between Type of loss of GCV during storage and Types of Biomass vendors

As the chi square value is less than 0.05 and the type of loss of GCV during storage is significantly associated with the types of vendors the null hypothesis is rejected.

Table 4.42 Type of loss of GCV during storage * Types of Biomass vendors

			Types of Biomass vendors			Total
			Stockiest	Middlemen or Agent	Farmer	
Type of loss of GCV during storage	Biomass blown away with the wind	Count	1	26	19	46
		% within Types of Biomass vendors	2.3%	41.9%	54.3%	32.6%
	Moisture addition in biomass	Count	32	21	9	62
		% within Types of Biomass vendors	72.7%	33.9%	25.7%	44.0%
	Adulteration of biomass with sand	Count	11	15	7	33
		% within Types of Biomass vendors	25.0%	24.2%	20.0%	23.4%
Total		Count	44	62	35	141
		% within Types of Biomass vendors	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			31.70957	4	.000	

4.5.4 GCV loss (%):-

H_{017}: There is no significance difference among mean GCV loss (%) of fuel mix

H_{117}: There is significance difference among mean GCV loss (%) of fuel mix

The mean value of GCV loss in mix% is maximum in case of biomass major mix (5.6974). In case of coal major mix it is (3.6236) and in case of biomass only it is (5.5865) which shows that GCV loss is minimum in case of coal major mix. There is significant difference among mean GCV loss% of fuel mixes. The ANOVA P value is less than 0.05. Hence the null hypothesis is rejected.

Table 4.43 Descriptives of GCV loss in mix (%)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
GCV loss in mix (%)	Biomass only	104	5.5865	2.96782	.29102	5.0094	6.1637	1.00	10.00
	Biomass Major Mix	23	5.6974	2.25912	.47106	4.7205	6.6743	1.24	9.76
	Coal Major Mix	14	3.6236	1.35361	.36177	2.8420	4.4051	1.14	5.24
	Total	141	5.4097	2.79431	.23532	4.9445	5.8750	1.00	10.00

Table 4.44 ANOVA Tool for GCV loss in mix (%)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
GCV loss in mix (%)	Between Groups	49.819	2	24.910	3.295	.040
	Within Groups	1043.321	138	7.560		
	Total	1093.140	140			

Table 4.45 Multiple Comparisons of GCV loss in mix (%)

Dependent Variable	(I) Type of mix	(J) Type of mix	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
GCV loss in mix (%)	Biomass only	Biomass Major Mix	-.11085	.63356	.983	-1.6119	1.3902
	Biomass only	Coal Major Mix	1.96297	.78276	.035	.1084	3.8175
	Biomass Major Mix	Coal Major Mix	2.07382	.93206	.071	-.1345	4.2821

4.6 OBJECTIVE 4:

To evaluate different transportation configurations which involve middle men (stockiest, contractors and transporters, etc.) that will add value in the existing supply chain

Through this objective we are trying to find out the different transportation methods used by the middlemen in supplying the feedstock from the farmers to the power generators and the value addition (in the form of using some new techniques of storage or using some new vehicles of transportation) these middlemen are doing in the supply chain.

For this, certain parameters were taken– Role in biomass supply chain, Types of biomass vendors, Mode of transporting biomass from field / storage to the power plant and Ways of storing biomass.

4.6.1 Role in biomass supply chain

When analysis was done for the role the vendors are playing in the supply chain it was found that 47.4% persons are playing the role of stockiest, 26.3% are playing the role of middlemen and other 26.3% persons are acting as farmers.

Table 4.46 Role in biomass supply chain

Role in Biomass supply chain		
	Frequency	Percent
Stockiest	18	47.4
Middlemen or Agent	10	26.3
Farmer	10	26.3
Total	38	100.0

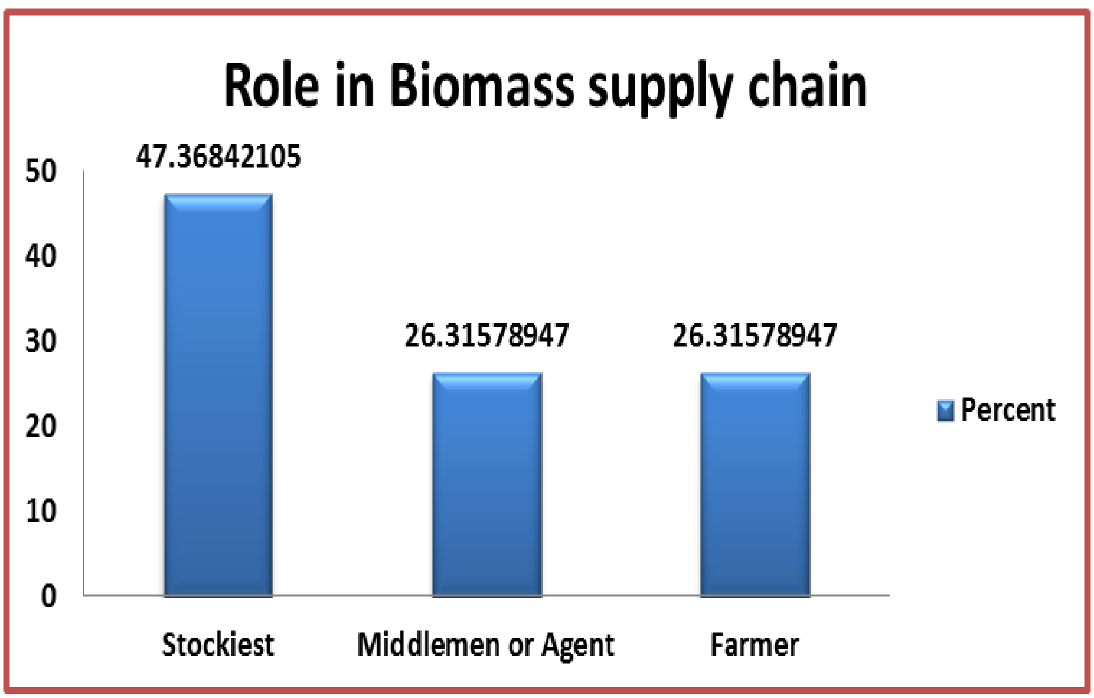

Figure 4.14 Role in biomass supply chain

4.6.2 Types of Biomass vendors

Mainly three types of Biomass vendors are supplying biomass from the farmers to the power generators. They are stockiest, middlemen and farmers. Mainly there are middlemen as can be seen in the table (44%).

Table 4.47 Types of Biomass vendors

Types of Biomass vendors		
	No.	%
Stockiest	44	31.2
Middlemen or Agent	62	44.0
Farmer	35	24.8
Total	141	100.0

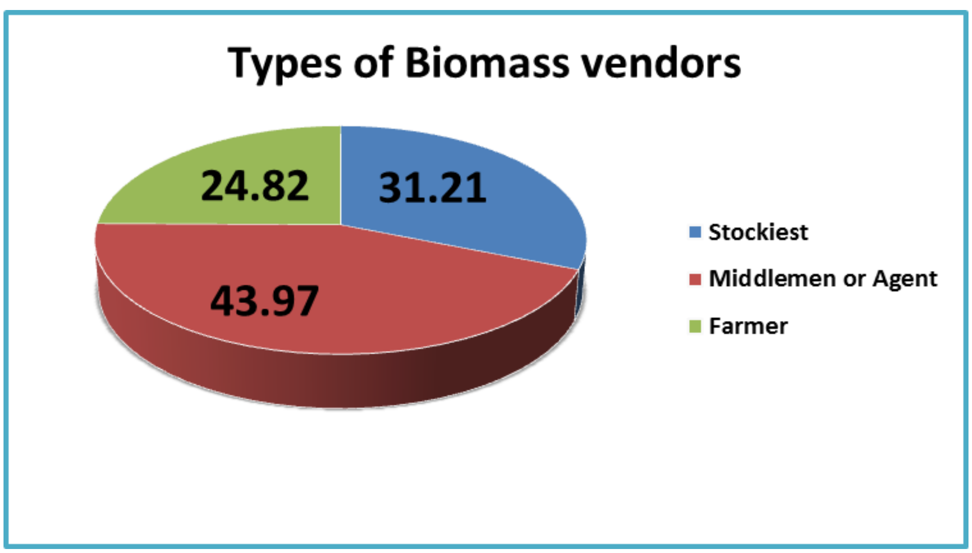

Figure 4.15 Types of Biomass vendors

4.6.3 Mode of transporting Biomass from field / storage to the power plant

Various means of transportation are used by the middlemen like tractor, trolley, loading truck. Mainly Tractor trolley (42.1%) and Tractor & Truck (47.4%) are used as can be seen in the table 4.48 below. Very less percentage of middlemen are using loading trucks as specific fuel consumption is more in trucks and it is affordable to use tractor and trolleys.

Table 4.48 Mode of transporting Biomass from field / storage to the power plant

Mode of transporting Biomass from field / storage to the power plant		
	Frequency	Percent
Tractor trolley	16	42.1
Loading truck	4	10.5
Tractor & Truck	18	47.4
Total	38	100.0

4.6.4 Ways of storing Biomass

Biomass is stored in various forms. In the survey done for the ways of storing Biomass it was found that 61.7% people leave the husk loose – at the farm land, while 29.1% people leave it loose at plant storage area with compacting and the remaining 9.2% people made briquettes out of the husk which is a very better way of storing it. As shown in table 4.49 below.

Biomass Briquettes is a biofuel substitute of charcoal and coal. They are used to heat, cook, and also used for generating energy, where they heat industrial boilers in order to produce electricity from steam. The most common use of the briquettes is in the developing world, where energy sources are not as broadly available.

Table 4.49 Ways of storing Biomass

Ways of storing Biomass		
	No.	%
Briquettes	13	9.2
Loose - At farm land	87	61.7
Loose - At plant storage area with compacting	41	29.1
Total	141	100.0

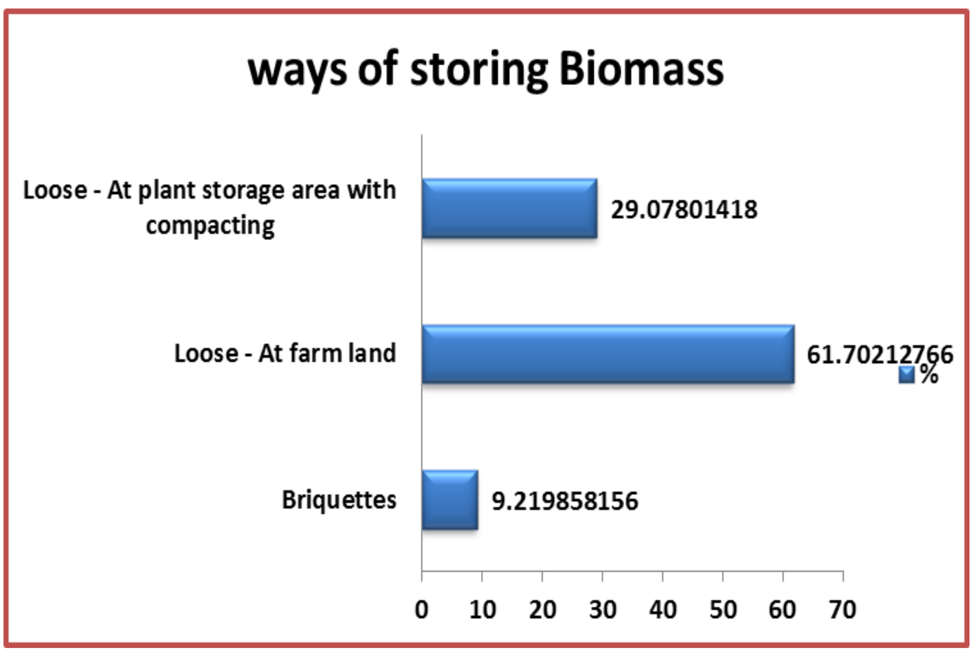

Figure 4.16 Ways of storing Biomass

4.6.5 Ways of storing Biomass * Type of mix

H_{018}: There is no significant association between Ways of storing and Type of mix.

H_{118}: There is significant association between Ways of storing and Type of mix.

When the analysis was done for the ways of storing biomass and the type of mix it was found that Briquettes are mainly formed when the mix is of either biomass only type (1.9%) or of biomass major mix type (47.8%). No briquettes are formed out of coal. Biomass is left loose at farm land when the mix is of Biomass only type (63.5%) and of biomass major mix type (47.8%). As shown in the table 4.50 below. The Chi square value is less than 0.05. This shows that there is a significant association between ways of storing Biomass and the type of mix. Hence, rejecting the null hypothesis.

Table 4.50 Ways of storing Biomass * Type of mix

			Type of mix			Total
			Biomass only	Biomass Major Mix	Coal Major Mix	
ways of storing Biomass	Briquettes	Count	2	11	0	13
		% within Type of mix	1.9%	47.8%	0.0%	9.2%
	Loose - At farm land	Count	66	11	10	87
		% within Type of mix	63.5%	47.8%	71.4%	61.7%
	Loose - At plant storage area with compacting	Count	36	1	4	41
		% within Type of mix	34.6%	4.3%	28.6%	29.1%
Total		Count	104	23	14	141
		% within Type of mix	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			51.397	4	.000	

4.6.6 Ways of storing Biomass * Types of Biomass vendors

H_{019}: There is no significant association between ways of storing and type of biomass vendors.

H_{119}: There is significant association between ways of storing and type of biomass vendors.

Briquettes are formed from biomass for storage when mainly the types of vendors are the stockiest (18.2%) and the farmer (5.7%). It is left loose at the farm land mainly when the vendors are farmers (62.9%) and middlemen (69.4%). It is left loose at plant storage area with compacting at this time the types of vendors are all the three types. This shows that there is no significant association between the ways of storing biomass and the types of biomass vendors. The chi square value is more than 0.05 hence accepting the null hypothesis. As shown in Table 4.51 below.

Table 4.51 Ways of storing Biomass * Types of Biomass vendors

Ways of storing Biomass * Types of Biomass vendors						
			Types of Biomass vendors			Total
			Stockiest	Middlemen or Agent	Farmer	
Ways of storing Biomass	Briquettes	Count	8	3	2	13
		% within Types of Biomass vendors	18.2%	4.8%	5.7%	9.2%
	Loose - At farm land	Count	22	43	22	87
		% within Types of Biomass vendors	50.0%	69.4%	62.9%	61.7%
	Loose - At plant storage area with compacting	Count	14	16	11	41
		% within Types of Biomass vendors	31.8%	25.8%	31.4%	29.1%
Total		Count	44	62	35	141
		% within Types of Biomass vendors	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			7.571	4	.109	

4.6.7 <u>Mode of transporting Biomass from field / storage to the power plant * Role in Biomass supply chain</u>

H_{020}: There is no significant association between mode of transporting Biomass from field / storage to the power plant and Role in biomass supply chain

H_{120}: There is significant association between mode of transporting Biomass from field / storage to the power plant and Role in biomass supply chain

While doing the analysis for the mode of transportation and the role of suppliers in the biomass supply chain it was found that that there is no significant association between the above two parameters as in either case i.e. stockiest, middlemen, farmers the mode of transportation is tractor trolley, loading truck or tractors.

The null hypothesis is accepted as the chi square value is more than 0.05 as shown in table 4.52 and which shows that there is no significant association between the mode of transporting biomass from field / storage to the power plant and the role in biomass supply chain.

Table 4.52 Mode of transporting biomass from field / storage to the power plant * Role in biomass supply chain cross tabulation

			Role in Biomass supply chain			Total
			Stockiest	Middlemen or Agent	Farmer	
Mode of transporting Biomass from field / storage to the power plant	Tractor trolley	Count	6	4	6	16
		% within Role in Biomass supply chain	33.3%	40.0%	60.0%	42.1%
	Loading truck	Count	2	2	0	4
		% within Role in Biomass supply chain	11.1%	20.0%	0.0%	10.5%
	Tractor & Truck	Count	10	4	4	18
		% within Role in Biomass supply chain	55.6%	40.0%	40.0%	47.4%
Total		Count	18	10	10	38
		% within Role in Biomass supply chain	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square			Value	df	Asymp. Sig. (2-sided)	
			3.495	4	.479	

B. QUALITATIVE DATA ANALYSIS

Qualitative data was collected from the power plants of the 9 companies. The Business Heads and the employees of the various companies represent the demand side of the supply chain. Various problems, challenges and advantages as discussed by the Business heads are given below in table 4.53.

Table 4.53 Major Problems, Challenges and Advantages faced by Employees

	Problems and Challenges	Advantages
DCM Shriram Ltd.	Biomass husk is available in maximum quantity in the months of April and May. Acute shortage is in the months of September and October. Requirement of biomass is throughout the year but company has to smoothen, the peaks in demand.	Having a mud segregation unit which separates sand/mud from biomass feedstock making it easier and faster to generate energy from the waste.
ShriramRayons Ltd.	High investment is required, to modify existing machineries so as to use biomass as a feedstock instead of coal.	Have very strong network of suppliers and traders due to which supply of husk is regular and shortage of biomass is not there.
Kalpataru Power	It has never used any fossil fuel as a feed stock for power generation. Right from the inception of the project the company is totally dependent on biomass.	Tonk and Ganganagar Plants have logistics infrastructure to collect approx. 200,000 MTs of such inputs every year
Surya Chambal Power Ltd.	It is an IPP (independent power producer) and producing power using biomass is the only business of this company so if husk is not available in good quantity all the year round as may be due to heavy rains or any other natural calamity then it has to suffer losses and face certain	They are using a combined harvestor machine for removing the waste from the fields and cutting it from the very bottom. For solving the problem of farmers the company had installed special plates in the harvesting machines so that the remains of the plants could be

	problems. Problem of viability of project due to unavailability of biomass may be there. As per policy of Government of Rajasthan Renewable Energy Conservation Promotion policy 2004 there was restriction of using biomass by other plant within 70 km radius,(table 4.54) but unfortunately there are a lot of plants using biomass near this area due to which prices of biomass are continuously rising as can be seen in the figure 4.17 below and also the availability is hindered.	removed from a very lower side and least part of the plant is wasted.
Orient Green Power Company Rajasthan Pvt Ltd.	They are facing the problem of storing the biomass as traders and middle men are demanding very high prices and less biomass is available in their nearby area so they have to procure it from far away distances which creates the problem of logistics and supply chain.	Ash content in biomass is less so minimum wastage is there and this as can be used as a manure.
Goyal Proteins Ltd.	Different pricing and procurement strategies are adopted by different power producers for procurement of biomass.	Biomass availability is done by local vendors and farmers.

Ruchi Soya Industries Ltd.	High investment and construction cost per KW and higher operation cost for the biomass project.	They have made many storage locations in the villages and near the factory where they collect and supply the biomass as and when required.
Shiv Edibles Ltd.	High investment is required in the boiler and other machineries	Procurement cost of biomass is less as compared to coal so quite beneficial.
S.M. Environmental Technologies Pvt. Ltd.	There is no organized market for the supply of biomass feed stock.	Availability of infrastructure to feed the biomass in the boiler.

Table 4.54 Biomass power plants reserved area in Rajasthan

Capacity (MW)	**Area reserved (Radius in km)**
5	60
More than 5 and up to 7.5	75
More than 7.5 and up to 10	80
More than 10 and up to 12.5	85
More than 12.5 and up to 15	90
More than 15 and up to 20	100

Source : Report of Dalkia Energy services Ltd., New Delhi submitted to RRECL

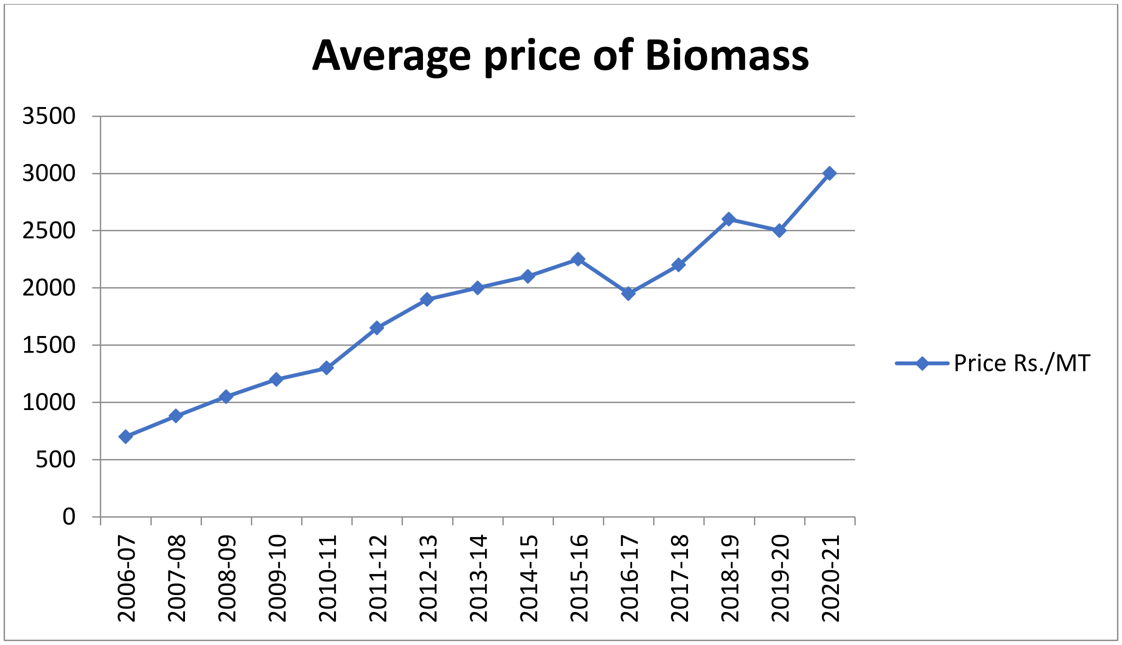

Figure 4.17 Average price of biomass from the year 2006 to 2020-21

Source: Data collected from Kota local industries

Middleman represents both the supply and demand sides of the supply chain so their voice was also captured as they are important part of the supply chain representing both the ends. Major challenges and advantages as discussed with them are given below in table 4.55.

Table 4.55 Major Problems, Challenges and Advantages faced by Middlemen

Major Problems and Challenges	Major Advantages
• Biomass has potential fire hazard having tendency to self-ignite, so they have to be very precautious and careful. • Biomass husk being highly voluminous, it is a challenging task to contain the cost of transportation. • Biomass has tendency to blow away with wind very easily during transporting in open trolleys.	• There is a scope of rendering their services to more than one company at a time. So there are good business opportunities in this area. • Use of Harvester (agriculture machineries) will increase the business opportunities to them • Supplying Biomass to various power producing companies is a source of additional income for them apart from other businesses.

Farmers represent the supply side of the supply chain. Major challenges and advantages as discussed with the farmers are given below in table 4.56.

Table 4.56 Major Problems, Challenges and Advantages faced by Farmers

Major Problems and Challenges	Major advantages
• Their sowing area (generation of crop residue) is generally far away from the power plants (energy producer). • The credit limit time forced by energy producing companies is not preferred. Collection of payment needs lot of follow-ups which is not favored by farmers.	• Agriculture machines and methods in mechanized way is assisted by energy producers like use of harvester which cut the crop residues from the very bottom i.e. an efficient method to maximize the generation of Biomass. • Good source of income apart from their agriculture farming and other such businesses.

The Interpretation and data analysis as shown above is generated after applying several tests on the data and then by verifying them, through testing the hypothesis. It was done in both quantitative and qualitative manner.

CHAPTER-5

Conclusions

and

Suggestions

5.1 Conclusions

From this Research and study it has been concluded that the use of renewable energy is on the rise across the world with many projects which are ready to capture the wind energy, hydro energy, solar energy and biomass energy are coming up in the near future. More and more entrepreneurs and industrialists across our country are becoming aware about the use of Biomass husk and they are venturing into this area to make the best use of biomass husk.

In Rajasthan and also in Kota the conditions are on the better side i.e. the excess amount of biomass husk left after consumption and utilization in brick kilns and after being used for manure & fodder etc. is being used by the farmers who are either using the husk for heating or burning purpose or supplying it to the middlemen. Who in turn are supplying it to power producing companies but still initiatives need to be taken by the local and government authorities.

5.1.1 Major Conclusions from quantitative data analysis

- It has been concluded that Biomass of mustard crop is available mainly in the months of March, April, and May and lowest availability of mustard husk is in the monsoon season and in the months of September and October.

- To make the biomass available from the fields to the power producers vendors play a major role. Stockiest(31.2%), middlemen(44%) and farmers(24.8%) are acting as vendors and are mainly procuring the biomass husk and supplying it to the various companies who are generating power. It is concluded that mainly middlemen (44%) are acting as vendors.

- From the research it has been concluded that various challenges are being faced by the companies in making the biomass available to the power producers- for (63.8%) employees demand supply gap is a major challenge, for (67.4%) employees entry of new consumer of biomass in the region is a big hurdle, Heavy rains leading to crop damage is a problem for 78% employees, for (63.1%) drought is a big challenge.

- It has been concluded that various problems are being faced by the people who are involved in the business of biomass. The major problems are- biomass husk catches fire very easily, problem of rains due to which moisture is added into the husk, problem of transporting, overloading, chances of accident if trolleys are overloaded with the biomass husk.

- For procuring the biomass various strategies are adopted by the employees of the power generating companies viz. (66.7%) of the employees of the various companies have subcontracted the procurement activity by developing middlemen in the supply chain, (59.6%) of the employees of the companies have increased the in-house storage capacity within the plant and (58.2%) employees monitor the rates of the market to wait for the favorable price of biomass in the region.

- After testing the hypothesis, for the analysis related to types of Biomass vendors and the type of mix, it is concluded that there is a significant association between the types of Biomass vendors and the type of mix as biomass only(52.9%) is mainly procured by the middlemen and coal major mix(85.7%) is mainly procured by the stockiest, biomass major mix(78.3%) is mainly procured by the stockiest, p value was found to be less than 0.05, and therefore null hypothesis is rejected.

- Mean values of procurement cost of Biomass, in Biomass only (mix) is Rs. 2391.12, in biomass major mix is Rs. 2670. and in coal major mix is Rs. 2756.57 The results revealed that the procurement cost of biomass is maximum when majorly coal is used and lowest when purely biomass is used hence it can be concluded that there is a significant association between procurement cost of biomass and the fuel mix, p value is less than 0.05 therefore rejecting the null hypothesis.

- The mean value of handling cost of biomass from storage area to boiler feed is maximum in case of Biomass only mix i.e.251.96 and least in case of coal major mix i.e. 202.86 and in biomass major mix its value is 205.57. It is concluded that that there is a significant association between handling cost of biomass from storage area to boiler feed and the fuel mix. The P value after applying ANOVA test is less than 0.05, therefore null hypothesis is rejected.

- The total procurement cost is Maximum (mean value) in case of coal major mix (3447.16) and lowest in case of employees using Biomass only (2593.97) and the mean value in biomass major mix is (3037.59).Therefore the conclusion is that there is a close association between total procurement cost per MT of mix and the fuel mix and it shows that it is economic viable to use biomass feed stocks in comparison to coal. As P value is less than 0.05. Therefore Null hypothesis is rejected.

- By testing the hypothesis and applying the tests it is concluded that there is a significant association between average transportation cost of biomass per Km per MT (in Rs.) and the supplier, as the transportation cost's mean value is maximum in case of middlemen (1.34) and minimum in case of stockiest(1.08), the P value is less than 0.05 hence null hypothesis is rejected.

- The average storage cost of biomass with respect to stockiest is 1444.44 (mean value) that of middlemen is 1531.00 and that of farmer is 1510.00 and the ANOVA P value is more than 0.05 therefore null hypothesis is accepted. The conclusion is that there is no significant association between average storage cost of biomass in different fuel mix. Very little differences are there in the storage costs of various suppliers.

- After doing the data analysis it was found and concluded that the mean value of last year consumption of Biomass major mix is 50026.87 MT. The mean value of Biomass only is approx. 49150.68 and the mean value of coal major mix is 26656.14, which shows that there is a significant association between the last year consumption of biomass and the type of fuel mix. The P value is less than 0.05. Hence rejecting the null hypothesis.

- The mean value of last year quantity of Biomass trading (in MT) as done by the middle men is 35049.00 as done by the farmer is 26000.00 and as done by the stockiest is 32000.00 which shows that maximum trading is done by the middlemen therefore it is concluded that there is a significant association between the quantity of biomass trading and the supplier. The P value is less than 0.05. Hence rejecting the null hypothesis.

- The analysis shows that the mean value of ash content of coal major mix is 30.46% and of biomass major mix is 9.60% and of biomass only is 8.17%. So the conclusion is that coal major mix has more of ash content which is just a waste for the companies so the power producers should use more of biomass as a feedstock and decrease the amount of coal as a feed stock to reduce the amount of waste. The results show that there is a close association between ash content of mix % and the fuel mix. This proves that using biomass feedstock is economically viable if considered in terms of ash content. The P value is less than 0.05. Hence rejecting the null hypothesis.

- A bird's eye view shows that in the 9 companies surveyed by us, 104 employees are using 0% coal and 100% biomass depicted as (Biomass only), 23 employees are using majorly biomass 93-94% and very less coal 6-7% shown as(Biomass major mix) and Only 14 persons are using around 93-94% coal and 6-7% biomass shown as(Coal major mix).

- When analysis was done for the boiler efficiency it was found that when 76.9% employees are using (Biomass only) at that time boiler efficiency is in the range of 70-80%.The efficiency is between 80-90% when 92.9% employees are using coal mix. The conclusion is that when maximum use of biomass is used as feedstock, efficiency to produce power is quite good. The Pearson chi square value is less than 0.05. Hence rejecting the null hypothesis. Therefore the conclusion is that there is a significant association between boiler efficiency and the type of mix.

- Maximum thermal unit efficiency i.e. around 45% is achieved when the type of mix is biomass only, the thermal efficiency is between 30-40% when the type of mix used is biomass major type and when the coal major mix is used at that time the efficiency is between 25-30%. The Pearson chi square value is less than 0.05. Hence rejecting the null hypothesis. It can be concluded that there is a significant association between thermal unit efficiency and the types of mixes.

- Maximum power is generated in the range of (81-100%) when Biomass only is used by the companies i.e. when companies are using more of biomass at that time maximum power is generated. When majorly coal mix is being used i.e. 78.6% at that time only 6-10% power is generated. Hence the conclusion is that there is a significant association between power generated due to biomass with respect to total power generation in the plant and the type of mix. Null hypothesis is therefore rejected.

- The GCV of coal mix is maximum amongst all the mixes, its mean value is 4280.179 whereas the GCV of biomass only is having the mean value as 3142.288 and the mean value of biomass major is 3183.610. Therefore the conclusion is that there is a close association between GCV of mix and the types of mixes, rejecting the null hypothesis.

- The cost absorbed by the companies in generating 1000KCal of energy using the various mixes of biomass and coal is approximately the same, not much difference is there in their mean values. Cost of coal major mix (mean value is 0.8081) is approx. same as the cost of biomass only mix (0.8539) and biomass major mix (0.9558). The conclusion is that there is no significant association of the cost used to generate 1000KCal of energy with the fuel mixes. The ANOVA value is more than 0.05. Hence accepting the null hypothesis.

- It is concluded from the analysis for the type of loss of GCV for biomass during storage and the type of mix that maximum loss in GCV is due to the adulteration in coal major mix by addition of moisture. Even biomass major mix is mainly adulterated by moisture. Biomass only is mostly blown away with wind. Therefore there is significant association between type of loss of GCV during storage and the type of mix. The Chi square value is less than 0.05. Hence rejecting the null hypothesis.

- It can be concluded that type of loss of GCV during storage is significantly associated with the types of biomass vendors as when the type of vendor is the stockiest (72.7%) then maximum GCV loss is due to the moisture addition in biomass. In case of farmer (54.3%) maximum loss is due to the wind and in the case of middlemen (41.9%) also maximum loss is by the wind. As the chi square value is less than 0.05. Rejecting the null hypothesis.

- It can be concluded that the that there is significant difference among mean GCV loss% of fuel mixes as the mean values of GCV loss in mix% is maximum in case of biomass major mix (5.6974). In case of coal major mix it is (3.6236) and in case of biomass only it is (5.5865) which shows that GCV loss is minimum in case of coal major mix. The ANOVA P value is less than 0.05. Hence rejecting the null hypothesis.

- It is concluded that there is a close association between the ways of storing biomass and the type of mix. When the analysis was done it was found that briquettes are mainly formed when the mix is of either biomass only type (1.9%) or of biomass major mix type (47.8%). No briquettes are formed out of coal major mix (0%). When the mix is of Biomass only type (63.5%) then mainly it is left open at the farm land. Very few organizations are making the briquettes. Instead more companies should concentrate on making the briquettes as in them GCV loss is very less and compact form of husk is there so easy to store and handle. The Chi square value is less than 0.05. Therefore rejecting the null hypothesis.

- When the type of vendor is the stockiest (50%) then mainly the biomass is left loose at the farm land when the middlemen (69.4%) are supplying the biomass husk at that time also the husk is left loose at the farms . Therefore it is concluded that there is no significant association between the ways of storing biomass and the types of biomass vendors. The chi square value is more than 0.05 hence accepting the null hypothesis.

- It is also concluded that there is no significant association between the mode of transporting biomass from field / storage to the power plant and the role of suppliers in the biomass supply chain as in either case i.e. stockiest, middlemen, farmers the mode of transportation is tractor trolley, loading truck or tractors. Null hypothesis is accepted as the chi square value is more than 0.05.

5.1.2 Major Conclusions from qualitative data analysis

- It is concluded that the strategy of using mixes of coal and biomass is making the companies and industries very good competitive players in the power generation field.

- Companies have reduced the operation costs and power generating costs by the use of mix of coal and biomass both.

- More and more companies and industries are now coming up in this area of generating power using the husk and residues of the agriculture waste left out in fields.

- It is concluded that the use of new equipment and machines by the companies to cut the crop residue and waste has improved the situations in fields. Both middlemen and farmers are happy and satisfied by it.

- Farmers are becoming more aware about the use of husk left out in fields and they are also becoming conscious with regards to the atmospheric pollution level that will rise if waste is burnt in fields.

- Middlemen indicated that they are rendering their services to more than one company at a time i.e. they are supplying biomass to many power producing companies at a time.

- Biomass has potential fire hazard, having tendency to self-ignite. During interaction with middlemen it was disclosed that such incidents of catching fire takes place during peak summer in the warehouses and dump yards. So they have to be very precautious and careful.

- The credit limit time forced by energy producing companies is not preferred. Collection of payment needs lot of follow-ups which is not favored by farmers

5.2 Suggestions

5.2.1 Suggestions for Companies

- Technical ways by which one can measure the GCV of biomass should be developed in companies so that more precise and sound results can be obtained.

- Companies and organizations are suggested to publish and make the public aware about the various sources and uses of biomass so that more and more businessmen and traders come forward and make full use of this eco-friendly fuel.

- The companies should use biomass only mix as a feed stock as it is ecofriendly, it contains less of ash as compared to coal and its procurement cost is also less as compared to coal.

- The companies which are leaving the husk loose must concentrate on forming the briquettes as they will yield a better GCV as compared to lose husk in which GCV loss is seen

5.2.2 Suggestions for Government Authorities

- The government authorities are suggested to develop structured market (mandi) of biomass so that more farmers and traders will involve themselves into the business of biomass and more trading will be done of this renewable fuel.

- New technological advancements and innovations are needed in this area so as to maximize the generation of biomass.

- Government authorities should help and guide the farmers and peasants with regard to the benefits of not burning the husk of the crops instead helping the farmers in making full utilization of the waste and husk left over in fields.

- As compared to other renewable fuels like solar power, wind power, hydro power not much awareness is there about Biomass power. The authorities and agencies should make people (who are involved in making bricks in brick kilns and other small scale business men) aware about the merits of this renewable fuel.

- As per guidelines of Government of Rajasthan Renewable energy promotion policy 2004 there was a restriction of using biomass by other companies in a radius of 70 Km but many companies are not following this policy and are coming up with their power plants within this area, due to which prices of biomass husk are continuously rising and industrialists are facing problem with regard to availability and prices of biomass. The local authorities should take care of these issues.

- Availability of Biomass for power generation is not ascertained through any government funding reports.

5.2.3 Suggestions for Vendors and Farmers

- Since biomass is a byproduct of crop farmers are not giving due importance to maximize the quantity of biomass generated. Farmers are therefore suggested to give due weight age to the husk generated out of the crops and use this husk for power generation and not burn it in the farmland as it creates a lot of pollution.

- Farmers are suggested to use the ash (residual disposal left after burning of biomass) in the form of manure in fields.

Summary

Chapter 1

An Overview of Biomass power generation and its supply chain management

1.1. Introduction

Biomass is defined as any organic matter that is available on a renewable or recurring basis. It comprises of all crop residues and materials derived from plants, which includes agricultural crops and trees, wood and wood residues, grasses, aquatic plants, animal manure, municipal residues, and other left over materials. Its major benefit is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Biomass is an important source of energy and the most important fuel all over the world after coal, oil and natural gas.

1.2. Biomass resources

Various resources of biomass are available like energy crops, agro industrial waste, agriculture wastes, municipal solid wastes and forest waste. One of the most promising sectors for growth in bioenergy production is in the form of residues from agriculture sector. Currently, the sector contributes less than 3% to the total bioenergy production.

1.3. Global scenario of biomass

Biomass – the largest energy source after coal, oil and natural gas is the most important renewable energy option at present and can be used to produce different forms of energy. Moreover, compared to other renewables, biomass resources are common and widespread across the globe. 18% of the energy consumed globally for heating, power, and transportation came from renewable sources in 2017. Nearly 60 percent of this came from modern renewables (i.e., biomass, geothermal, solar, hydro, wind, and biofuels) and the remaining 7.5% from traditional biomass (used in residential heating and cooking in developing countries).

Renewable made up 26.2 percent of global electricity generation in 2018. That's expected to rise to 45 percent by 2040. Most of the increase will likely come from solar, wind, and hydropower.

1.4. Overview of biomass in India

Sources of power generation range from conventional sources such as coal, lignite, natural gas, and oil to viable non- conventional sources such as wind, solar, hydro and nuclear and biomass. Renewable energy sector in India has experienced tremendous changes in the policy framework during the last few years.

In 2015, Prime Minister Narendra Modi set an ambitious goal for India to generate 175 gigawatts (GW) of renewable energy by 2022. According to latest data released by the Ministry of New and Renewable Energy, India has installed a total capacity of 74.79 GW of renewable power as of December 31, 2018.

Most of India's biomass electricity is being generated in Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka and Rajasthan. A lot of new capacity is being built in Punjab and Chhattisgarh as well. India with a total biomass capacity of around 1 GW is planning to increase it by 10 times to 10 GW by 2020. Between 200-600 acres of land are required to support 1 MW of Biomass capacity. This is much more than what is required for even a thin film of solar energy, which is around 10 acres. The large land requirements make biomass energy scaling a difficult proposition. However, it has a great use in niche applications where there is a large amount of crop and animal residue/waste available.

1.5. Overview of Biomass in Rajasthan

Rajasthan has immense potential in form of, Mustard husk, soya bean husk, Rice, Juli-flora (Vilayati Babool) husk and other agriculture residues for the biomass fuel. Biomass-based Power Projects totaling to 113 MW have already been registered with RREC.

The Rajasthan state consists of 33 districts and the average cultivated area of Rajasthan state for the past three years is coming around 2,24,79,599 Ha. The total generation of biomass in districts is around 5,56,51,058 MT/Yr, whereas the total consumption is 5,00,89,905 MTs/yr and therefore the surplus is 55,61,153 MT/Yr**.** Maximum amount of biomass is left in Kota, Bikaner, Jaisalmer, Jodhpur and Bundi districts which can be used for power generation. The major portion of wheat stalks, barley stalks, paddy hay, jowar stalks, bajra stalks, maize stalks are consumed by animal as fodder and these biomass should not used as a fuel per the Policy of 2010. Mainly Mustard stalks/husks, soya bean stalks, guar stalks and groundnut stalks are in surplus which can be used for power generation as per the Rajasthan biomass fuels supply study.

1.6. Overview of Biomass in Kota

The amount of total Biomass generation in Kota is 21lakh MT/year. Whereas, the consumption is around 13lakh MT/Year and so the surplus amount i.e. 7lakh MT/Year can be utilized for power generation as per the biomass assessment study 2019.

Various companies and industries are operating in Kota which are using biomass for power generation DCM Shriram, Shriram Rayons, Kalpataru Power, Surya Chambal, Orient Green Power company Raj Pvt Ltd, Goyal Proteins, Ruchi Soya Industries Ltd, Shiv Edible Ltd, S.M. Environmental Technologies Pvt. Ltd., Sharda Solvent Ltd, Shriram EPC, Mangalam Cement.

Some of them are using purely biomass husk like Surya Chambal, Kalpataru power whereas some are using mix of biomass and coal like DCM Shriram and Shriram Rayons. The middlemen and farmers are happy and satisfied as they are having extra income from this business.

1.7. Biomass fuel and its properties

Biomass is available in a number of different formats like fine dust, sawdust, chips, pellets, briquettes, and bales. Instead of burning the loose biomass fuel directly, it is more useful to compress it into briquettes (compressed block of coal or biomass material), bales and pellets thereby increasing its usefulness and convenience. Such biomass in the dense briquetted form can either be used directly as fuel instead of coal in the traditional chulhas and furnaces.

1.8. Benefits and Challenges of biomass based power generation

Some of the benefits are- distributed generation, base load power, suited for rural areas, Ability to have small KW scale power production, rural economic upliftment, carbon neutral and efficient utilization of renewable biological sources.

Highly voluminous material, availability, seasonal restrictions and efficiency are some of the challenges faced in using biomass**.**

1.9. Biomass Supply chain

Biomass energy production requires the flow of biomass material from the land to its ultimate end use. Along the way, biomass passes through a series of processes in what is called the biomass supply chain. Various stages of biomass supply chain are biomass field collection, loading and processing, transportation, unloading and handling, storage and last is energy exploitation.

Various elements of the biomass supply chain require unique sets of information, knowledge, technology and activity. These include growing, harvesting, transporting, aggregating, storing and converting biomass into some useful form. The main characteristics of the supply chain, that influence the logistics efficiency, are that the raw materials are produced over large geographical areas, have a limited availability window, and often are handled as very voluminous material. All these activities are made possible by the farmers, middlemen and the employees of the power generating company. They are the key stakeholders of the supply chain.

Chapter 2

Review of literature

2.1 Introduction

A review of literature of various studies related to Biomass as an energy fuel, a source of power generation and its effective logistics and supply chain management shows that very limited research has been carried out in this area especially in the Indian context. Various International and National research papers were studied and reviewed to find out the research gap**. Areas of Literature reviewed in this chapter include biomass for bioenergy and biofuels, biomass for power generation and supply chain management of Biomass.**

2.2 Research related to biomass for bioenergy and biofuels

2.2.1 **Faaij (2007)** have pointed out in their paper that biomass is a versatile energy source that can be used for production of heat, power, and transport fuels, as well as biomaterials and, when produced can be used on a sustainable basis, it can also make a large contribution to reducing greenhouse gas (GHG) emissions. In this publication the authors have mentioned the importance of biomass as a bioenergy. A comparison is also done with other fuel options.

2.2.2 **Anil Kumar et al (2015)** have discussed in their paper about Biomass energy resource, its potential, energy Conversion and policy for promotion as implemented by Government of India. The total installed capacity for electricity generation in India is 2666.64 GW as on 31st March 2013. Renewable energy is contributing 10.5% of total generation out of which 12.83% power is being generated using biomass. India has surplus agricultural and forest area which comprises about 500 million metric tons of biomass availability per year. In India total biomass power generation capacity is 17,500 MW.

2.3 Papers related to biomass power generation

2.3.1 Hao & Luo (2012) have put forward in the research article, some counter measures for the orderly development of China's biomass power generation which are as follows:

- Investigation and Assessment of the Biomass Resources,
- Development Mechanism for Biomass Power Generation Industry,
- Good Environment for Investment, and Well-coordinated and Unified regulation Institution.

In this paper Constraints in China's Biomass Energy Development has also been discussed which are as follows:

- ➢ Lack of Systematic and Scientific Overall Planning
- ➢ Independent Technology Research and Development Ability for Biomass Power Generation
- ➢ The High Cost of Biomass Power Generation
- ➢ The Relevant Law and Government Support Policy
- ➢ Single Investment and Financing Channel and Unsound Market Mechanism
- ➢ Insufficient Supporting Mechanism

2.3.2 Purohit & Chaturvedi (2018) have stated in their paper that modern bioenergy is being recognized as an increasingly important low-carbon resource by policy-makers around the world to meet climate policy targets. In India also, there is a clear recognition of the significant role of bioenergy in electricity generation as well as in other applications. Bioenergy for power generation can be used in two different forms—pelletized and non-pelletized. The non-pelletized form has been used for a long time for co-firing in coal thermal power plants or biomass power plants.

Biomass pellets are now being used extensively and international trade is increasing year on year, largely driven by climate policy targets adopted by developed countries. The authors then estimate the cost of 100% biomass pellet-based electricity production and assess its financial viability.

2.4 Literature related to supply chain management of biomass

2.4.1 **Allen, Browne et al.** have stated in their paper the supply chain considerations and costs of using biomass fuel on a large scale for electricity generation at power stations. It is at this scale of use that the logistics of biomass fuel supply are likely to be both complex and potentially problematic, and logistics costs will have an important bearing on the total delivered cost of biomass (i.e. the total cumulative cost of biomass fuel at the point of delivery to a power station). It is important to recognize that logistics costs and the integrated management of logistics activities can be vital to the success or failure of a product or industry, especially in the case of a new industry.

2.4.2 **Agustina et al (2018)** have stated in their paper that Biomass is one of the most important renewable energy sources besides geothermal, wind, hydropower and solar, which can substitute fossil energy. Over the years, researchers have been investigating the process of producing and converting biomass into bioenergy, but the importance of logistics was detected recently. Critical parameters of supply chain management and logistics are efficiency and effectiveness. This paper presents a literature review of articles published in journal articles from 1992 to 2017, which includes the bioenergy production interface and logistical issues and supply chain management.

Chapter 3

Research methodology

3.1 Introduction of Research methodology

Research methodology consists of all the methods & techniques used by the researcher to conduct the research. It is a systematic method for solving a problem. It specifies the flow of research in a step by step way. Essentially, the procedure by which researchers go about their work of describing, explaining and predicting phenomena is called research methodology.

The aim of this research is to estimate the cost of procuring biomass feed stock and to analyze the loss of calorific value in various stages of supply chain (harvesting, storing, handling and transportation) so that power stations will get biomass fuel of right specification, in the right quantity, at the right time from resources which are typically diverse and are seasonally dependent.

3.2 Research tool design

The questionnaire method was used for primary data collection. Besides questionnaire other methods like interviews were also adopted to enhance the progress of data collection through questionnaire and to observe closely the hidden and unexplored aspects related to the objectives of the study.

3.3 Objectives of the Study

To ascertain the extent of economic viability of using biomass feed stocks with respect to fossil fuels for the power producers.

To illustrate how procurement mix of existing biomass feed stock reduces overall power generation costs and assures regular availability of feed stocks.

To evaluate the loss of GCV of Mustard husk biomass feedstock during various stages of Supply Chain Management.

To evaluate different transportation configurations which involve middle men (stockiest, contractors and transporters, etc.) that will add value in the existing supply chain.

3.4 Research Hypothesis

1 H_0: There is no significant difference in cost of biomass procured by companies for power generation using different mixes of fuel.

H_1: There is a significant difference in cost of biomass procured by companies for power generation using different mixes of fuel.

2 H0: There is no significant difference in GCV loss of biomass procured by companies for power generation using different mixes of fuel.

H_1: There is a significant difference in GCV loss of biomass procured by companies for power generation using different mixes of fuel.

3 H0: There is no significant association between Supply chain stake holders and Mode of transportation of biomass

H_1: There is a significant association between Supply chain stake holders and Mode of transportation of biomass

3.5 Research Variables

Some of the variables are Procurement cost of Biomass, Handling cost of Mix, Total procurement cost, Transportation cost, Storage cost, Gross calorific value of the mix, Type of loss of GCV during storage and GCV loss (%) of Fuel Mix

3.6 Data:

Primary data is collected through structured questionnaire consisting of close ended questions. Primary data is information collected specially for the research purpose. It is often collected after the researcher has gained an insight into the issue by reviewing secondary research i.e. through Review of Literature.

Secondary Data is collected from Published journals, literatures and reference books, newspapers, magazines as well as reports published in science direct journals, MNRE annual reports, biomass assessment study reports, Bioenergy India magazine etc.

Qualitative data is collected through interviews conducted of key persons of companies, selected traders and farmers. The qualitative analysis was done using interview method. In this, interview schedules were prepared for three stakeholders namely employees, traders and farmers. We had interaction with business heads of nine companies We had detailed discussion with them regarding their strategies, future prospects, problems and advantages of the use of biomass for power generation.

Conversation was held with the selected middlemen regarding logistics problems in the business of biomass, the merits and demerits they find in this business and other troubles that come their way while supplying this fuel from the farmers to the power producers. We had interacted with some of the farmers also. With their limitations in literacy levels, they were not able to define our requirement up to the expectations. So an interview was conducted with them regarding the advantages and disadvantages in selling the biomass husk to the middlemen or to the power producers.

3.7 Sampling Methodology

a Employees

Total 12 companies were there having different business models which were using Biomass as a feedstock for power generation in Kota region. Out of these 12 companies only 9 companies responded.

In our survey we found respondents covering procurement, quality, technical/ engineering and costing departments having approximately 250 employees. We tried to contact 125 employees (50% of total population) and successfully 141 employees responded. All visits to the companies were arranged by their respective HR departments. It was not an easy task to survey the employees of private/ public organizations as the matter is confidential in terms of strategies and figures.

b Traders

The information regarding the traders who are involved in the supply chain management of biomass was gathered through the companies. In total 38 traders/middlemen responded us and shared their business model as well as the difficulties faced by them. Purposive sampling was done to select the traders.

3.8 Statistical Methods & Tools

Mainly One way ANOVA and Chi square tests were applied for carrying out the analysis and for testing the hypothesis.

3.9 Significance of Research

Through this research we are trying to estimate the cost of procuring biomass feed stock and to analyze the loss of calorific value in various stages of supply chain (harvesting, storing, handling and transportation) so that power stations will get biomass fuel of right specification, in the right quantity, at the right time from resources which are typically diverse and are seasonally dependent.

Very few research studies have been done in this area especially in Kota region. So this study will definitely help the present power generating companies and the upcoming companies with regard to the type of mix (biomass and coal) they should use in the form of feedstock for generation of power.

3.10 Research Gap

Review of literature suggests that many studies have been done in the areas related to biomass energy, biomass power generation and supply chain management of biomass but very few or no studies have been done in the areas related to the procurement cost of using biomass fuel, logistics and the means of supplying and transporting biomass from the farmers end to the power generating end of the companies. This study begins with analyzing the stakeholders (employees, traders and farmers) of the various power producing companies, who are using biomass as a feedstock for power generation in Kota region of Rajasthan**.** The research work becomes more relevant in this region as it addresses the supply chain considerations and the costs and benefits of procuring biomass fuel on large scale for electricity generation at power stations.

3.11 Limitations

- In order to make the study more precise, specified and objective oriented, this research has been confined to the Kota region. Data analysis is done for the middlemen, employees and transporters attached to the selected power producers of Kota region. Sample drawn from the selected region shall not be applicable to any other part of country as supply chain is very specific to location and product handled.

- Very large data sampling was not possible as there are only few companies in Kota region who are into this business of generating power using biomass.

- Not possible to collect data from the farmers as they are not willing to respond and tell much about themselves.

- Due to competition in procurement of biomass companies are not publishing and declaring statistics and data and they are not willing to disclose their procurement strategies also.

- Secondary data not available to a larger extent as very less periodicals and magazines are available.

Chapter 4

Interpretation and analysis of data

The purpose of the chapter is to highlight the outcomes of the study, resulted by the application of statistical tools for testing the hypothesis.

4.1 Parameters of General Profile

The prominent hardship in business of biomass, types of traders, locality of traders, total power generation capacity of thermal unit and type of boiler,

4.2 Objective 1

To illustrate this objective we have used four parameters namely Availability, Procurement, Consumption & Residual Disposal.

4.2.1 Availability

- The Highest availability months of Biomass are from March to May and the lowest availability months of biomass are from August to October.

- Various challenges are being faced by the power generating companies in making the biomass available like heavy rains leading to crop damage, Entry of new consumer of biomass in the region etc.

- Several strategies are adopted by the power generating companies for increasing the power generation through Biomass viz. maximize the procurement from nearest source to cater the high demand supply gap, Sub-contracting of procurement activity by developing middle men in supply chain management

- Biomass only is mainly procured by the middlemen and the farmers. Biomass major mix and coal major mix is mainly procured by the stockiest.

4.2.2 Procurement

- Procurement cost of Biomass

H_{02}: There is no significant difference among mean procurement costs of biomass in different fuel mix.

H_{12}: There is significant difference among mean procurement costs of biomass in different fuel mix.

Procurement cost of biomass is highest in case when majorly coal (Rs. 2756.57) is being used and lowest when purely biomass (Rs. 2391.12) is used which shows that there is a significant association between procurement cost of feedstock with the fuel mix and p value is less than 0.05 hence rejecting the null hypothesis.

- Handling cost of Mix

H_{03}: There is no significant difference among mean handling costs of biomass in different fuel mix.

H_{13}: There is significant difference among mean handling costs of biomass in different fuel mix.

The mean value of handling cost of biomass from storage area to boiler feed is maximum in case of Biomass only i.e. 251.96 and least in case of coal major mix i.e. 202.86 which shows that there is a significant association between handling cost of biomass from storage area to boiler feed and the fuel mix. The P value is less than 0.05 hence we reject the null hypothesis.

- Total procurement cost

The total procurement cost is the sum of procurement cost and the handling cost of biomass. The total procurement cost is maximum in case of coal major mix (Rs.3447.16) and lowest in case of employees using biomass only (Rs.2593.97).

H_{04}: There is no significant difference among mean total procurement costs of biomass in different fuel mix.

H_{14}: There is significant difference among mean total procurement costs of biomass in different fuel mix.

This shows that there is a close association between total procurement cost of biomass mix in different fuel mix. As ANOVA P value is less than 0.05. Therefore null hypothesis is rejected.

- Transportation cost

It is the cost incurred by the company in transporting biomass from the source to the place of power generation.

H_{05}: There is no significant difference among mean transportation costs of biomass in different fuel mix.

H_{15}: There is significant difference among mean transportation costs of biomass in different fuel mix.

The transportation cost's mean value is maximum in case of middle men (1.34) and minimum in case of stockiest (1.08), which shows that there is a significant association among mean transportation costs of biomass in different fuel mix. As ANOVA P value is less than 0.05, hence rejecting the null hypothesis.

- Storage cost

The average storage cost of Biomass is not much different with respect to the stockiest, Middlemen and farmer.

4.2.3 Consumption

It is the amount of Biomass consumed by the various power generating organizations.

H_{07}: There is no significant difference among mean consumption of biomass in different fuel mix.

H_{17}: There is significant difference among mean consumption of biomass in different fuel mix.

The mean values of the three mixes are different. Therefore there is a significant association between the last year consumption of biomass and the type of fuel mix. The p value is less than 0.05 hence rejecting the null hypothesis.

4.2.4 Residual Disposal

Residual disposal is the waste left out after Biomass or coal is burned to generate electricity. The amount of ash content in coal is very high as compared to Biomass.

H_{09}: There is no significance difference among mean ash content as residual of Fuel Mix

H_{19}: There is significance difference among mean ash content as residual of Fuel Mix

The mean value of ash content of coal major mix (30.46%) is highest as compared to biomass major mix (9.60%) and of biomass only (8.17%), which shows that coal has more of ash content and so there is a close association between ash content of mix % and the fuel mix. The P value is less than 0.05. Hence rejecting the null hypothesis

4.3 Objective 2

For this we have taken certain parameters- Biomass mix ratio, Technical and engineering changes, Power generated due to biomass with respect to total power generation in the plant and gross calorific value

4.3.1 Biomass mix ratio

- This ratio shows the combination in the feedstock i.e. the amount of coal and the amount of biomass used in the mix which is feeded into the boiler.

4.3.2 Technical and Engineering changes

- It was found that many engineering and technical changes are done by the power plants to aid in the use of biomass, like use of additional infrastructure to feed the biomass in the boiler. Modifications are done in the boiler area, resizing of steam control unit is also done.

4.3.3 Power generated due to biomass with respect to total power generation in the plant

- Maximum power is generated by Biomass only i.e. when companies are using more of biomass at that time maximum power is generated. When majorly coal mix is being used at that time very less power is generated. The Pearson chi square value is less than 0.05 which shows that there is a significant association between power generated due to biomass with respect to total power generation in the plant and the type of mix. Hence rejecting the null hypothesis.

4.3.4 Gross calorific value of the mix

- It is the heat produced by combustion of unit quantity of a solid or liquid fuel when burnt at a constant volume The Gross calorific value of coal is higher than that of biomass i.e. on burning coal we get higher amount of heat energy as compared to biomass.

H_{013}: There is no significance difference among mean Gross calorific value of Fuel Mix

H_{113}: There is significance difference among mean Gross calorific value of Fuel Mix

The GCV of coal mix is highest, whereas the GCV of biomass only and biomass major is less. The ANOVA P value is less than 0.05 which shows that there is a close association between GCV of mix and types of mixes. Hence rejecting the null hypothesis.

4.4 Objective 3

For this we have taken certain parameters -Type of loss of GCV during storage, Type of loss of GCV during storage * Type of Biomass vendors, GCV loss (%)

4.4.1 Type of loss of GCV during storage

Biomass can be blown away with the wind, as biomass has to be left in open; addition of moisture is there into it during the rainy season. It is adulterated with sand and stone pieces etc. It gets mixed with the foreign particles therefore its heat producing capacity gets reduced and hence the GCV is lost. Coal has a high calorific value and adulteration of coal is less as compared to biomass so less heat loss is there in case of coal.

4.4.2 Type of loss of GCV during storage * Types of Biomass vendors

When the type of vendor is the farmer and middlemen then maximum GCV loss is due to wind. Biomass gets blown away with the wind and when the type of vendor is the stockiest then maximum GCV loss is due to the moisture addition in biomass.

H_{016}: There is no significant association between Type of loss of GCV during storage and Types of Biomass vendors

H_{116}: There is significant association between Type of loss of GCV during storage and Types of Biomass vendors

As the chi square value is less than 0.05, we reject the null hypothesis and we can say that the type of loss of GCV during storage is significantly associated with the types of vendors. The ANOVA P value is less than 0.05 which shows that both the above factors are significantly associated.

4.4.3 GCV loss (%)

H_{017}: There is no significance difference among mean GCV loss (%) of Fuel Mix

H_{117}: There is significance difference among mean GCV loss (%) of Fuel Mix

The GCV loss in mix% is highest in case of Biomass major mix and least in coal major mix. The ANOVA P value is less than 0.05 hence rejecting the null hypothesis. Therefore there is significant difference among mean GCV loss% of fuel mixes.

4.5 Objective 4

For this we have taken certain parameters – Types of Biomass vendors, Ways of storing Biomass, Ways of storing Biomass*type of mix, , Mode of transporting Biomass from field / storage to the power plant * Role in Biomass supply chain.

4.5.1 Types of biomass vendors

Mainly three types of Biomass vendors are supplying biomass from the farmers to the power generators. They are stockiest, middlemen and farmers

4.5.2 Ways of storing Biomass

Biomass is stored in various forms like it can be left loose at farm land, loose - At plant storage area with compacting, or it can be stored in the form of briquettes. Mostly it is left loose at farm land.

4.5.3 Ways of storing Biomass * Type of mix

Briquettes are mainly formed when the mix is of either biomass only type or of biomass major mix type. No briquettes are formed out of coal. When the mix is of Biomass only type, then mainly it is left open at the farm land.

H_{018}: There is no significant association between Ways of storing and Type of mix.

H_{118}: There is significant association between Ways of storing and Type of mix.

There is a close association between the ways of storing biomass and the type of mix .When we did the analysis it was found that Briquettes are mainly formed when the mix is of either biomass only type or of biomass major mix type. No briquettes are formed out of coal. When the mix is of biomass only type then mainly it is left open at the farm land. The Chi square value is less than 0.05. Therefore it shows that there is a significant association between ways of storing biomass and the type of mix. Hence rejecting the null hypothesis.

4.5.4 Mode of transporting Biomass from field / storage to the power plant * Role in Biomass supply chain

H_{020}: There is no significant association between Mode of transporting Biomass from field / storage to the power plant and Role in Biomass supply chain

H_{120}: There is significant association between Mode of transporting Biomass from field / storage to the power plant and Role in Biomass supply chain

While doing the analysis in which we compared the mode of transportation and the role of suppliers in the biomass supply chain we found that there is no significant association between the above two parameters as in either case i.e. stockiest, middlemen, farmers the mode of transportation is tractor trolley, loading truck or tractors. Accepting the null hypothesis as the chi square value is more than 0.05.

4.6 Qualitative data analysis

Various problems, challenges and advantages as discussed by the Business heads are given below.

Problems and challenges

- Biomass husk is available in maximum quantity in the months of April and May. Acute shortage is in the months of September and October.

- High investment is required, to modify existing machineries so as to use biomass as a feedstock instead of coal.

- Different pricing and procurement strategies are adopted by different power producers for procurement of biomass.

- There is no organized market for the supply of biomass feed stock.

Advantages

- Having a mud segregation unit which separates sand/mud from biomass feedstock making it easier and faster to generate energy from the waste.

- They are using a combined harvester machine for removing the waste from the fields and cutting it from the very bottom.

- Biomass availability is done by local vendors and farmers.

- Ash content in biomass is less so minimum wastage is there and this as can be used as a manure**.**

Major problems/challenges as discussed by the middlemen and farmers.

- Biomass has potential fire hazard having tendency to self-ignite, so they have to be very precautious and careful.

- Biomass husk being highly voluminous, it is a challenging task to contain the cost of transportation.

- Their sowing area (generation of crop residue) is generally far away from the power plants (energy producer).

- The credit limit time forced by energy producing companies is not preferred. Collection of payment needs lot of follow-ups which is not favored by farmers.

Major Advantages as discussed by the middlemen and farmers

- Agriculture machines and methods in mechanized way are assisted by energy producers like use of harvester which cut the crop residues from the very bottom i.e. an efficient method to maximize the generation of Biomass.

- Supplying Biomass to various power producing companies is a source of additional income for them apart from other businesses.

Chapter 5

Conclusions and Suggestions

5.1 Major Conclusions of the quantitative Research

- To make the biomass available from the fields to the power producers vendors play a major role. Stockiest(31.2%), middlemen(44%) and farmers(24.8%) are acting as vendors and are mainly procuring the biomass husk and supplying it to the various companies who are generating power. It is concluded that mainly middlemen (44%) are acting as vendors.

- From the research it has been concluded that various challenges are being faced by the companies in making the biomass available to the power producers- for (63.8%) employees demand supply gap is a major challenge, for (67.4%) employees entry of new consumer of biomass in the region is a big hurdle, Heavy rains leading to crop damage is a problem for 78% employees, for (63.1%) drought is a big challenge.

- After testing the hypothesis, for the analysis related to types of Biomass vendors and the type of mix, it is concluded that there is a significant association between the types of biomass vendors and the type of mix as biomass only (52.9%) is mainly procured by the middlemen and coal major mix (85.7%) is mainly procured by the stockiest, biomass major mix (78.3%) is mainly procured by the stockiest, P value was found to be less than 0.05, and therefore null hypothesis is rejected.

- Mean values of procurement cost of Biomass, in Biomass only (mix) is 2391.12 Rs, in biomass major mix is 2670 Rs. and in coal major mix is 2756.57 The results revealed that the procurement cost of biomass is maximum when majorly coal is used and lowest when purely biomass is used hence it can be concluded that there is a significant association between procurement cost of biomass and the fuel mix, P value is less than 0.05 therefore rejecting the null hypothesis.

- The mean value of handling cost of biomass from storage area to boiler feed is maximum in case of Biomass only mix i.e. 251.96 and least in case of coal major mix i.e. 202.86 and in biomass major mix its value is 205.57. It is concluded that that there is a significant association between handling cost of biomass from storage area to boiler feed and the fuel mix. The P value after applying ANOVA test is less than 0.05, therefore null hypothesis is rejected.

- The total procurement cost is Maximum (mean value) in case of coal major mix (3447.16) and lowest in case of employees using Biomass only (2593.97) and the mean value in biomass major mix is (3037.59).Therefore the conclusion is that there is a close association between total procurement cost per MT of mix and the fuel mix and it shows that it is economic viable to use biomass feed stocks in comparison to coal. As P value is less than 0.05. Therefore Null hypothesis is rejected.

- By testing the hypothesis and applying the tests it is concluded that there is a significant association between average transportation cost of biomass per Km per MT (in Rs.) and the supplier, as the transportation cost's mean value is maximum in case of middle men (1.34) and minimum in case of stockiest(1.08), the P value is less than 0.05 hence null hypothesis is rejected.

- The average storage cost of Biomass with respect to stockiest is 1444.44(mean value) that of middlemen is 1531.00 and that of farmer is 1510.00 and the anova P value is more than 0.05 therefore null hypothesis is accepted. The conclusion is that there is no significant association between Average storage cost of Biomass (in Rs.) and the Supplier. Very little differences are there in the storage costs of various suppliers.

- The analysis shows that the mean value of ash content of Coal major mix is 30.46% and of Biomass major mix is 9.60% and of biomass only is 8.17% .So the conclusion is that coal major mix has more of ash content which is just a waste for the companies so the power producers should use more of biomass as a feedstock and decrease the amount of coal as a feed stock to reduce the amount of waste. The results show that there is a close association between ash content of mix % and the fuel mix. This proves that using biomass feedstock is economically viable if we consider in terms of ash content. The P value is less than 0.05. Hence rejecting the null hypothesis.

- A bird's eye view shows that in the 9 companies surveyed by us, 104 employees are using 0% coal and 100% Biomass depicted as (Biomass only), 23 employees are using majorly biomass 93-94% and very less coal 6-7% shown as (Biomass major mix) and Only 14 employees are using around 93-94% coal and 6-7% biomass shown as(Coal major mix).

- When analysis was done for the boiler efficiency it was found that when 76.9% employees are using (Biomass only) at that time boiler efficiency is in the range of 70-80%. The efficiency is between 80-90% when 92.9% employees are using coal mix. The conclusion is that when maximum use of biomass is used as feedstock, efficiency to produce power is quite good. The Pearson chi square value is less than 0.05 hence rejecting the null hypothesis. Therefore the conclusion is that there is a significant association between boiler efficiency and the type of mix.

- Maximum power is generated in the range of (81-100%) when biomass only is used by the companies i.e. when companies are using more of biomass at that time maximum power is generated. When majorly coal mix is being used i.e. 78.6% at that time only 6-10% power is generated. Hence the conclusion is that there is a significant association between power generated due to biomass with respect to total power generation in the plant and the type of mix. Null hypothesis is therefore rejected.

- The GCV of coal mix is maximum amongst all the mixes, its mean value is 4280.179 whereas the GCV of biomass only is having the mean value as 3142.288 and the mean value of biomass major is 3183.610. Therefore the conclusion is that there is a close association between GCV of mix and the types of mixes, rejecting the null hypothesis.

- It is concluded from the analysis for the type of loss of GCV for biomass during storage and the type of mix that maximum loss in GCV is due to the adulteration in coal major mix by addition of moisture. Even biomass major mix is mainly adulterated by moisture. Biomass only is mostly blown away with wind. Therefore there is significant association between type of loss of GCV during storage and the type of mix. The chi square value is less than 0.05. Rejecting the null hypothesis.

- It can be concluded that Type of loss of GCV during storage is significantly associated with the Types of Biomass vendors as when the type of vendor is the stockiest (72.7%) then maximum GCV loss is due to the moisture addition in biomass. In case of farmer (54.3%) maximum loss is due to the wind and in the case of middlemen (41.9%) also maximum loss is by the wind. As the chi square value is less than 0.05. Rejecting the null hypothesis.

- It can be concluded that the that there is significant difference among mean GCV loss% of fuel mixes as the mean values of GCV loss in mix% is maximum in case of Biomass major mix (5.6974). In case of coal major mix it is (3.6236) and in case of biomass only it is (5.5865) which shows that GCV loss is minimum in case of coal major mix. The ANOVA value is less than 0.05 hence rejecting the null hypothesis.

- It is concluded that there is a close association between the ways of storing biomass and the type of mix. When the analysis was done it was found that Briquettes are mainly formed when the mix is of either biomass only type or of biomass major mix (47.8%) type. No briquettes are formed out of coal major mix (0%). When the mix is of Biomass only (63.5%) type then mainly it is left open at the farm land. Very few organizations are making the briquettes. Instead more companies should concentrate on making the briquettes as in them GCV loss is very less and compact form of husk is there so easy to store and handle. The Chi square value is less than 0.05. Therefore rejecting the null hypothesis.

- When the type of vendor is the stockiest (50%) then mainly the biomass is left loose at the farm land when the Middlemen (69.4%) are supplying the biomass husk at that time also the husk is left loose at the farms . Therefore it is concluded that there is no significant association between the ways of storing Biomass and the types of Biomass vendors. The chi square value is more than 0.05 hence accepting the null hypothesis.

- It is concluded that there is no significant association between the mode of transporting biomass from field / storage to the power plant and the role of suppliers in the Biomass supply chain as in either case i.e. stockiest, middlemen, farmers the mode of transportation is tractor trolley, loading truck or tractors. Null hypothesis is accepted as the chi square value is more than 0.05.

5.2 Major Conclusions of qualitative analysis

- It is concluded that the strategy of using mixes of coal and biomass is making the companies and industries very good competitive players in the power generation field.

- Companies have lowered the operation costs and power generating costs by the use of mix of coal and biomass both.

- More and more companies and industries are now coming up in this area of generating power using the husk and residues of the agriculture waste left out in fields.

- It is concluded that the use of new equipment and machines by the companies to cut the crop residue and waste has improved the situations in fields and middlemen and farmers both are happy and satisfied by it.

- Middlemen indicated that they are rendering their services to more than one company at a time i.e. they are supplying biomass to many power producing companies at a time.

- Biomass has potential fire hazard, having tendency to self-ignite. During interaction with middlemen it was disclosed that such incidents of catching fire takes place during peak summer in the warehouses and dump yards. So they have to be very precautious and careful.

- The credit limit time forced by energy producing companies is not preferred. Collection of payment needs lot of follow-ups which is not favored by farmers

5.3 Suggestions

Suggestions for Companies

- ➢ Technical ways by which one can measure the GCV of biomass should be developed in companies so that more precise and sound results can be obtained.

- ➢ Companies and organizations are suggested to publish and make the public aware about the various sources of biomass and the various uses of biomass so that more and more businessmen and traders come forward and make full use of this eco friendly fuel.

- ➢ The companies which are leaving the husk loose must concentrate on forming the briquettes as they will yield a better GCV as compared to loose husk in which GCV loss is seen.

Suggestions for Government authorities

- ➢ The government authorities are suggested to develop structured market (mandi) of biomass so that more farmers and traders will involve themselves into the business of biomass and more trading will be done of this renewable fuel.

- New technological advancements and innovations are needed in this area so as to maximize the generation of biomass.

- Government authorities should help and guide the farmers and peasants with regard to the benefits of not burning the husk of the crops and also help the farmers in making full utilization of that waste and husk left over in fields.

- As compared to other renewable fuels like solar power, wind power, hydro power not much awareness is there about Biomass power. The authorities and agencies should make people (who are involved in making bricks in brick kilns and other small scale business men) aware about the merits of this renewable fuel.

- As per guidelines of Government of Rajasthan Renewable energy promotion policy 2004 there was a restriction of using biomass by other companies in a radius of 70km but many companies are not following this policy and are coming up with their power plants within this area, due to which prices of biomass husk are continuously rising and industrialists are facing problem with regard to availability and prices of biomass. The local authorities should take care of these issues.

Suggestions for Vendors and farmers

- Since biomass is a byproduct of crop farmers are not giving due importance to maximize the quantity of biomass generated. Farmers are therefore suggested to give due weightage to the husk generated out of the crops and supply this husk for power generation and not burn it in the farmland as that creates a lot of pollution.

- Farmers are suggested to use the ash left out after biomass is burnt as it has many properties of good manure.

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Published Research Papers

BIOMASS POWER GENERATION: A CASE STUDY OF TWO BIOMASS BASED POWER PLANTS OPERATING IN KOTA DISTRICT OF RAJASTHAN

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Abstract: Technologies to produce electricity from biomass through combustion and heating are on the rise. Various different technologies are used for the production of electricity through biomass. Caused by the logistic frame conditions of biomass production, storage and transportation as well as the possibility to use the thermal energy for community heating, decentralized power plants are the most economical. The use of Biomass is continuous on the rise as it has emerged as a viable energy source for generating power.

Biomass energy generates far less emissions than fossil fuels. Its use leads to environment benefits particularly to the reduction of atmospheric CO2 concentrations. In India the principal competing source for electricity is the coal based power. Associated with conventional electric power plants are some negative social and environmental externalities. Throughout the coal and nuclear fuel cycles there are significant environmental and social damages, contrarily biomass energy cost is highly variable depending upon the source, location etc. In this research paper a review and study is done of two Biomass based power plants operating in Kota district of Rajasthan .These plants are using Biomass as a feedstock for the generation of power.

Keywords: **Power, electricity, biomass, feed stock.**

1. Introduction

All organic matter is known as biomass, and the energy released from biomass when it is eaten, burnt or converted into fuels is called biomass energy. Biomass provides a clean, renewable energy source that could dramatically improve our environment, economy and energy security. Biomass energy generates far less air emissions than fossil fuels.

Biomass Energy in India: India had set up around 500 MW of Biomass Capacity by 2007 and has increased it by almost 150 MW since then to reach around 1 GW capacity in 2010. Most of India's' Biomass Electricity is being generated in Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka and Rajasthan. A lot of new capacity is being built in Punjab and Chattisgarh as well. India with a total biomass capacity of around 1 GW is planning to increase it by 10 times to 10 GW by 2020. Between 200-600 acres of land are required to support 1 MW of Biomass capacity. This is much more than what is required for even thin film solar energy which is around 10 acres. The large land requirements make Biomass energy scaling a difficult proposition. However, it has a great use in niche applications where there is a large amount of crop and animal residue/waste available.

Biomass Energy in Rajasthan: The Government of Rajasthan has accorded a high priority to setting up power projects based on non conventional energy sources in the State. With a view to promote generation of power from these sources, Government of Rajasthan issued a "Policy for Promoting Generation for Electricity from Non Conventional Energy Sources" in 1999. Keeping in view the requirements, this Policy has been amended from time to time. Lately, the Government of Rajasthan had issued "Policy for Promoting for Generation of Electricity from Biomass, 2010" (Policy-2010).

It was found that on an average about 92.5% of Biomass generated from the agricultural activity goes for consumption in local for fodder, manure, fuel for thermal energy consuming industries, biomass power plants, brick kilns etc, and about only 7.5% is available for other activities or exported to nearby states. The major portion of wheat stalks, barley stalks, paddy hay, jowar stalks, bajra stalks, maize stalks are consumed by animal as fodder and these biomass should not used as a fuel per the Policy of 2010. Mainly Mustard stalks, husks and soyabeen stalks are used for power generation as can be seen from their generation and consumption pattern. There is a surplus of 11,62,679 tons /year of Mustard stalks and husks. Similarly, there is a surplus of 3,32,178 tons/year of Soyabeen stalks and husks which can be used as feedstock in the power generators . This mustard husk, which is considered a total waste and not even used as fodder for cattle, is very light with a density of about 105 Kg/m^3.

Around 10-12 power plants are operating in the Kota region of Rajasthan. Some of them are totally dependent on biomass husk which is used as a feedstock for generating power. One of them is Surya Chambal and the other one is Shriram Rayons.

2. Surya Chambal Power Ltd.,

Formally known as Chambal Power Ltd., is a 7.5 MW capacity biomass (mustard husk) based power plant, located at Rangpur Village of District Kota, about 8 kms from Kota railway station on the banks of the Chambal river. The project was started in April 2004 and the plant was commissioned and synchronized with the Rajasthan Power Grid at 33 KV on 31st March, 2006. Thus starting the supply of power through its Gopal Mill GSS situated near Kota railway station. The company collects biomass for the whole year during the season of harvesting of mustard ie from March to May directly from the farmers. The biomass collected are the remains of the plants of mustard which are of no use to the farmer, which if not used would be burnt by them as parali which is a terrific cause of the air pollution. As can be seen in Punjab, Haryana, and NCR areas that the air pollution is on the rise which is on a large scale affecting the lungs and causing health issues.

Stubble burning in Punjab and Haryana in northwest India has been cited as a major cause of air pollution in Delhi. Smoke from this burning produces a cloud of particulates visible from space, and has produced a "toxic cloud" in New Delhi, resulting in declarations of an air-pollution emergency. Stubble burning is a relatively new phenomenon. Historically, farmers harvested and plowed fields manually, tilling plant debris back into the soil. When mechanized harvesting became popular in the 1980s, stubble burning became common because the machines leave stalks that are about one-foot tall. For solving this problem of farmers the company (Surya Chambal) had installed special plates in the harvesting machines so that the remains of the plants could be removed from a very lower side and least part of the plant is wasted.

Fig 1 : Combine Harvestor
Source:https://www.reference.com/business-finance/uses-combine-harvester-99d801be86cd7604

Technical details of Surya Chambal Biomass Plant are as follows:

- Power generation capacity of the thermal unit is 7.5 MW
- Type of boiler-Stoker Fired
- Boiler effeciency-70.1-80.0%
- Type of fuel used in the boiler- mustard husk
- Gross calorific value of biomass is around 3598 Kcal
- Ash content in biomass is around 6.8%

Fig 2 : Surya Chambal Biomass power plant Kota
Source: https://biomasspower.gov.in/document/Magazines/Bioenergy%20Magazine-MNRE/Issue%201-%20Sep%202009.pdf

The company has never used fossil fuel to support biomass and purchases Rs. 10–12 crore of biomass annually and thereby generates income for farmers and others in a region of 50 km radius from the plant. This has improved the quality of life of villagers who are now using cooking gas, buying television sets, motor cycles and even sending their children to the school. The company faced initial teething troubles. However, after carrying out certain technical modifications, it started yielding satisfactory results.

The company is also engaged in continuous improvement programs for operating the plant at optimum efficiency and projects for energy saving etc. The company is fully conscious of its social responsibilities and carries out various activities to raise the quality of life of the villagers of Rangpur, like repairing of roads, providing water and lighting facilities, development of village school, encouragement to children by providing them with scholarships, conducting various sports & games, awarding prizes at functions and competitions, conducting blood donation camps, joining and participating in religious functions/festivals, etc.

Having gained confidence by successfully running the plant at Rangpur, the company is now expanding and putting up another unit of 10 MW at Khatoli village in Kota, about 100 kms. from Rangpur. Its sister concerns, Sathyam Power Pvt. Ltd. is putting up a 10 MW plant at Merta Road in Nagaur district and Prakriti Power Pvt. Ltd. is putting up a 12 MW Power Plant at Gangapur city in Sawai Madhopur district.

3. Shriram Rayons

Another major producer of energy using Biomass is DCM Shriram Rayons located in Shriram Nagar Kota Rajasthan. Their power generation capacity is 9.2 MW. They have four boilers one is working completely on coal, another on Mustard husk and other two on coal and mustard husk both. Their daily consumption of biomass husk is around 300 tonnes. The price of Biomass husk at factory gate is approx 3000 Rs/MT which keeps on varying according to the availability of Biomass across the year. So roughly they purchase biomass of thirty six crores (36 crores) in a year which is quite less if we compare it with coal (price is around 6500Rs/MT) or any other fossil fuel used for generating power. The main advantage of such plants is the concern shown by organizations for the environment and use of renewable resources like biomass for generating energy which is otherwise a waste.

Technical details of Shriram Rayons Biomass Plant are as follows:

- Power generation capacity of the thermal unit is 9.2MW
- Type of boiler-Stoker Fired
- Boiler effeciency-70.1-80.0%
- Thermal unit efficiency of the plant is 30.1-40.0%
- Type of fuel used in the boiler- Soyabeen husk, mustard husk and Bituminous coal
- Gross calorific value of biomass is around 6000-6300Btu/lb
- Gross calorific value of coal is 7000-7500 Btu/lb
- Ash content in biomass is around 4.36%
- Ash content in coal is around 30-40%

Fig 3 : Shriram Rayons Kota
Source:https://www.financialexpress.com/industry/shriram-rayons-gets-green-nod-for-rs-163cr-expansion-project/358760/

On regular basis the company is engaged in advancement of the people living in nearby DCM Rayons, the company is also very well aware of its social responsibilities and carries out various activities to raise the quality of life of the villagers of nearby areas, like repairing of roads, providing water and lighting facilities, development of village school, provide encouragement to children by helping them with scholarships and also providing fees and books to the poor children, conducting various sports & games, awarding prizes and gifts at various functions and competitions, conducting blood donation and medical camps, joining and participating in religious functions/festivals, etc.

4. Challenges and Problems faced by both the companies

a) Prices

As per policy of Government of Rajasthan Renewable Energy Conservation Promotion policy 2004 there was restriction of using biomass by other plant within 70 km radius, but unfortunately there are a lot of plants using biomass near this area due to which prices of biomass become high and also the availability is hindered. There is no organized market for the supply of biomass feed stock. Different pricing and procurement strategies are adopted by different power producers for procurement of biomass.

b) Weather

It has a great influence on the proper harvest of biomass because it can reduce the yield of the crop, affect the biomass quality, and pose difficulty in the harvesting process by giving bad condition. The rainy season may harm the biomass stored on fields, moisture may affect the quality of biomass to be fed as a feedstock in the power generators.

c) Storage

The method of on-field storage has the advantage of low cost but on the other hand, biomass material loss is significant and biomass moisture cannot be controlled and reduced to a desired level, thus leading to potential problems in the power plant technological devices. Further-more, health and safety issues exist, such as the danger of spores and fungus formation and self-ignition due to increased moisture. Finally, the farmers may not allow on-farm storage of the biomass for a longer time period, as they may want to prepare the land for the next crop.

Several authors consider the use of intermediate storage locations between the fields and the power plant. For all biomass fuels in which the use of intermediate storage has been modeled, the fuel has to be transported twice by road transport vehicles (first from farm/forest to the intermediate storage facility and then from storage to the power station). This fact will result in a higher delivered cost than a system in which there is only one road transport movement (directly from farm/ forest to power station). Using an intermediate storage stage may add in the region of 10–20% to the delivered costs, as a result of the additional transportation and handling costs incurred.

d) High production cost

Nearly all the elements involved in biomass power generation mechanism suffer from the high cost, including raw materials, logistics service, equipment as calculated per unit of power generating capacity, maintenance of the grid-connecting device, and the overall operation of the plant. However, due to a lack of professional logistics operators, the biomass power plant has to purchase raw materials either at a designated place or directly from scattered farmers. There is simply no scale benefit in the acquisition of raw materials, therefore increasing purchasing cost. Furthermore, compared with conventional power plants, the generating capacity of biomass power plant is smaller, yet additional facilities are required, especially special storage fuel collecting and storage facilities. Moreover, power plants are responsible for power transformation and transmission onto the grid. The aforementioned factors contributed to high investment and construction cost per KW and higher operation cost for the biomass project.

e) Low density fuel

Most forms of biomass is very voluminous i.e. it has relatively low energy density per unit of mass compared to fossil fuels. This makes handling, storage and transportation more costly per unit of energy carried. Being lighter weight, approximately 2% by weight of Biomass is blown away with wind when stored in open area

f) Capital Investment

Biomass power generation is an emerging industry, of which the technology development and market cultivation demands a large amount of capital investment. Currently, while there lacks the investment and financing channel, the market operation mechanism is also incomplete. The maturing market mechanism gives rise to insufficient input of investment and R&D from the investors and production entities in both domestic and foreign markets, as well as the excessive development in certain aspects.

Three types of losses are considered during the storage of biomass in the biomass yard.

- **Land Settlement:** Biomass at bottom of heap gets mixed with sand and cannot be used in boiler. However, with leveling of ground and proper drainage system, land settlement loss can be reduced to about 0.4%
- **Loss of Fuel during Sand Storm:** This loss can be completely eliminated by covering the biomass with tarpaulin.
- **GCV Loss due to decaying of biomass:** Decaying loss can be reduced to about 1.5% by covering the biomass with tarpaulin and proper drainage.

5. Conclusion

Very little study has been done in the field of biomass especially in Rajasthan. Through this study one can come to know about the companies operating in Kota district which are using Biomass as a feed stock and generating power, various initiatives taken by the companies and the various problems and challenges faced by them. The study will definitely help in implementation of bio-energy production projects and the researchers for further improvement.

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A STUDY AND REVIEW OF THE SUPPLY CHAIN OF BIOMASS IN KOTA REGION OF RAJASTHAN

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Abstract: Biomass is a biological material derived from living or recently living organisms. It is used as a source of energy and refers to plants or plant-based materials. As energy sources, it can either be used directly by combustion to produce heat or indirectly after converting it to different forms of biofuel.

Biomass energy has become more popular recently as a new form of renewable energybut the nature of biomass energy is complicated due to the bulky, distributed nature of biomass feedstocks and the high volumes of the relatively low energy density materials that have to be moved to the conversion equipment.

In this study I am reviewing the supply chain of biomass in Kota region of Rajasthan. A typical biomass supply chain is comprised of severaldistinct processes. These processes may include groundpreparation and planting, cultivation, harvesting, handling,storage, in-field/forest transportation, road transportation andutilization of the fuel at the power station.

Keywords: Feedstocks, Biofuel, supplychain, power station

1. Introduction

All organic matter is known as biomass, and the energy released from biomass when it is eaten, burnt or converted into fuels is called biomass energy. Bioenergy production requires the flow of biomass material from the land to its eventual end use. Along the way, biomass passes through a series of processes in what is called the biomass supply chain. Various segments of the biomass supply chain require unique sets of knowledge, technology and activity. These include growing, harvesting, transporting, aggregating, storing and converting biomass. Additionally, and depending on the biomass type and the conversion technology used, pre-processing may also be a necessary step along the pathway from the land to energy use.

Renewable energy sources play a pivotal role in the current global strategies for reducing greenhouse gas emissions and partially replacing fossil fuels. Reserves of fossil fuels, such as oil, gas and coal are the main sources of energy spread over only a small number of countries, thus forming a fragile energy supply that is expected to reach its limit within the foreseeable future.

The usage of fossil fuels causes numerous environmental problems, such as atmospheric pollution, acidification and the emission of greenhouse gases. The development of cleaner and renewable energy sources appears as a meaningful intervention for addressing these problems. More specifically, biomass emerges as a promising option, mainly due to its potential worldwide availability, its conversion efficiency and its ability to be produced and consumed on a CO_2-neutral basis.

2. Characteristics of a Biomass supply chain

The biomass supply chain presents several distinctive characteristics that diversify it from a typical supply chain.

First of all, agricultural biomass types are usually characterised by seasonal availability. The period when these biomass types are available is very limited and is determined by the crop harvesting period, the weather conditions and the need to re-plant the fields. Since most of the biomass-to-energy applications to date concern single biomass use, there is a need of storing very large amounts of biomass for a significant time period, if year round operation of the power plant is desired.

Another characteristic of the biomass supply chain is that it has to deal with low density materials. As a result, there is increased need for transportation and handling equipment, as well as storage space. This problem is enhanced by the low heating value, which is partly due to the increased moisture of most agricultural biomass types. The low density of biomass increases further the cost of collection, handling, transport and storage stages of the supply chain.

Finally, several biomass types require customized collection and handling equipment, leading to a complicated structure of the supply chain. For example, there are different requirements on handling and transportation equipment and storage space configuration if biomass is procured in the forms of sticks or chips. Therefore, the form in which the biomass will be procured often determines the investment and operational costs of the respective bioenergy exploitation system, as it affects the requirements and design of the biomass supply chain.

The main characteristics of the supply chain, that influence the logistics efficiency, are that the raw materials are produced over large geographical areas, have a limited availability window, and often are handled as very voluminous material.

All of the abovementioned factors lead to increased supply chain cost and require significant attention in designing a biomass power plant, in order to reduce their negative impact to the financial yield of the entire system. The multi-biomass approach aims at reducing the impact of these factors.

The biomass supply chain is made up of a range ofactivities which include harvesting, baling, storing, drying and transport of the biomass both on the field and to the biorefinery& handling and transport of residues and by products. The activities required to supply biomass from its productionpoint to a power station are the following:

- Harvesting/collection of the biomass in the field/forest.
- In-field/forest handling and transport to move the biomass toa point where road transport vehicles can be used.
- Storage. Many types of biomass are characterized by seasonalavailability, as they are harvested at a specific time of the yearbut are required at the power station on a year-round basis; itis therefore necessary to store them. The storage point can belocated in the farm/forest, at the power station or at anintermediate site. The power plant Shriram Rayons has a storage site Khajoori near Kota which is at a distance from the plant. During the season of the cutting and harvesting of mustard i.e. from March to June the farmers and transporters collect the biomass husk of the mustard plant from the farmers at this site to be used by the plant throughout the year.
- Loading and unloading of the road transport vehicles.
- Once the biomass has been moved to the roadside it will need to be loaded to road transport vehicles for conveyance tothe power station. The biomass will need to be unloaded fromthe vehicles at the power station. In regions near Kota mostly tractors and trolleys are used for this purpose.
- Transport by road transportation vehicles.There are varyingopinions of whether it is more economical touse heavy goods vehicles or agricultural/forestryequipment for biomass transport to the power station.Ultimately, it appears to be a matter of the average transportdistance, biomass density, the carrying capacity andtravelling speed of the respective vehicles, as well as their
- Availability, which decides the final transportation vehicle.

- Processing biomass to improve its handling efficiency and thequantity that can be transported.Processing can occur at any stage in the supply chain but willoften precede road transport and is generally cheaper whenintegrated with the harvesting.

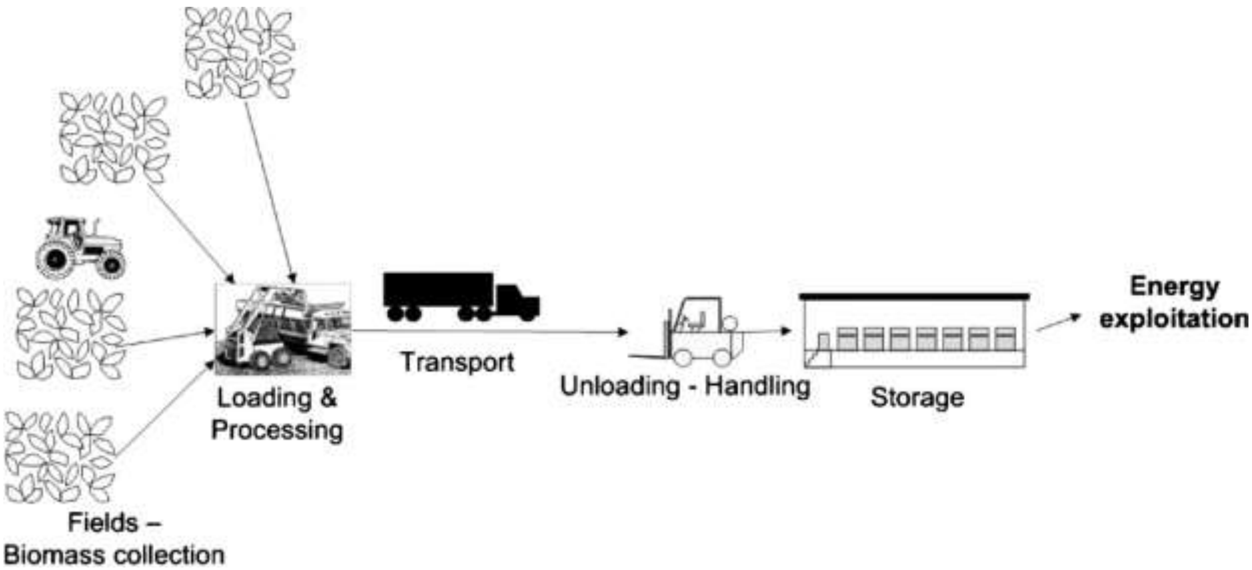

Fig. 1. Generic biomass supply chain design

Source: Logistics issues of biomass: The storage problem and the multi-biomass supply chainAthanasios A. Rentzelas ,Athanasios J. Tolis, Ilias P. Tatsiopoulos

3. Generation of Bioenergy from Biomass

Biomass to power value chain starts from collection and procurement of residual feedstock from various sources (so can even be exclusively produced from dedicated energy crops as well). After collection and procurement biomass is processed and subsequently transported, to the biomass power plant or taken to the storage yards (usually the biomass collection centers) for storage. The energy either as chemical fuel or heat from biomass acts as an ultimate driving force for transformation to power in turbine/engine-generator complex. The steps involved in the biomass to power production have been illustrated below:

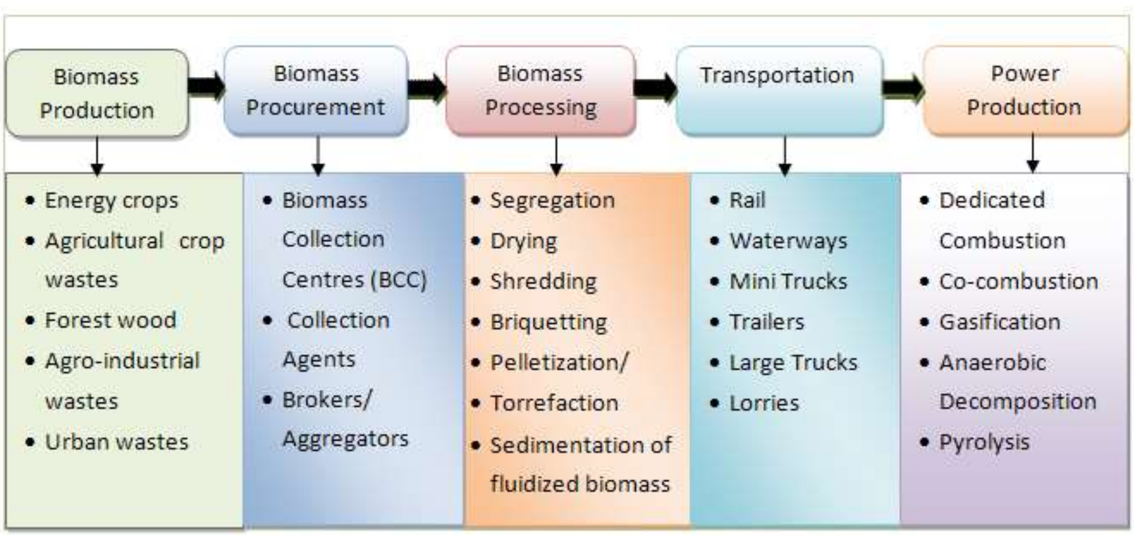

Fig 2: Generation of Bioenergy from Biomass

source: http://www.eai.in/ref/ae/bio/powr/biomass_power.html

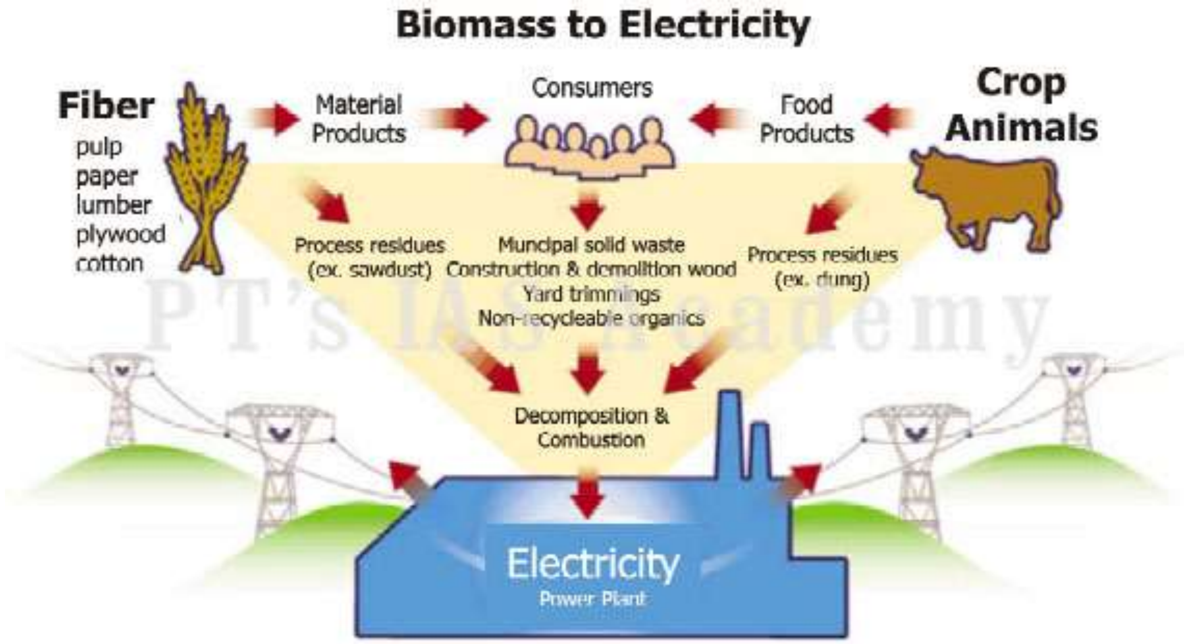

Fig:3

Source :https://solarthermalmagazine.com/producing-energy-breaking-biomass-instead-burning/

4. Major key players of the Biomass Supply chain

The major key players of the biomass supply chain are the farmers, middlemen, transporters and the employees. Establishing a biomass supply chain is of a great importance to the farmer as he is paid for the waste(biomass husk) which otherwise would have beenburnt or thrown away.

Then comes the middlemen or the traders/transporters who are helping the farmers on one end and employees of the power plant on the other end through transferring the biomass husk from the fields or the storage sites to the factory gate or to the site of power generation.

Finally the role comes of people working in the organizations or the power plants who are feeding the husk into the boilers and generating power. For them the biggest challenge is to make the regular and yearlong availability of the biomass husk especially in the rainy season when it becomes difficult to store and handle the voluminous bulk of biomass as the moisture content in it has to be taken care of before feeding it into the boiler.

Energy produced from renewable sources, such as biomass, is quiet popular these days due to the recent instability in fossil fuel energy prices. However, the process of using these alternative energies requires the development of new supply chains and a labor pool to manage them. Some technologies, like solar and wind energy, arenot so complicated in that the equipment captures natural energy in its immediate environment, converts it to electricity and then moves it to where it is needed via transmission lines. In other words, the energy resource is ‘delivered’ to the energy conversion technology by nature.

5. Problems and challenges in the biomass supply chain

There are a number of good technologies for converting biomass into usable energy, but almost all start from tree and plant based materials found spread over the landscape.The unique nature of each biomass project is in quite contrast to the fossil fuel industry model.

Perhaps the most difficult component of setting up a biomass energy system is establishing the mechanism to bring enough low density plant biomass to a central point for conversion to energy.

In the fossil fuel industry, standardization is a key to lowering production costs. The technologies and methods used in finding and delivering fossil fuels have evolved to be efficient and relatively uniformly applied, thus reducing costs.

In biomass projects, the distinct features of a particular feedstock in a particular location mean that the collection and delivery systems often have to be specially developed to match a particular project. Proper planning and review are important for developing an effective and efficient supply chain. A large biomass energy facility can cost lot of money and require 15 to 20 years to pay back capital costs. In case of power plants using biomass as feedstock the boilers used by them previously for the fossil fuels have to be modified and redesigned and this incurs them a cost.

Environmental sustainability is also an important concern for a biomass supply chain. Poor environmental planning can hurt the environment, damage the image of biomass energy, and limit available resources. Many power plants in India and also in Rajasthan had started few years back using biomass as a feedstock but due to lack of planning and due to unavailability of resources were closed and shut down.

Avery crucial step of the supply chain is to find out the locally occurring biomass resources that may be available for use. Once a suitable resource has been identified, the roles of individuals and organizations in the supply chain should be clarified. It is helpful to first review what biomass is and what properties make it suitable for conversion to energy or refining to bio-based products, in order to completely identify all potential sources of biomass for a supply chain. Biomass conversion technologies are usually selected to minimize complications due to contaminants or undesired properties.

6. Solutions and alternatives

Various alternatives are available to overcome the problems faced in the supply chain.

One strategy to maintain resource availability and reduce costs is by using multiple feedstocks. There are a number of conversion technologies that can use the same equipment to produce energy from different feedstocks or multiple biomass. This is convenient for short term purchasing because it allows purchasing of the cheapest usable biomass at a given point in time. In the long term, it also protects against major availability changes in a feedstock. During project development, fuel flexibility gives an extra margin of error for facilities that may use most of the regionally available pool of a single biomass feedstock. In years where the biomass supply becomes difficult, they may need to switch to a more frequently available biomass source. Looking at multiple feedstocks may be the only option for some facilities where one source alone cannot fulfill those facilities’ resource demands.

For example in Kota region companys like Shriram Rayons and Shriram Fetilisers are using mustard and soyabeen husk as feedstocks along with coal. Surya Chambal is using biomass husk as feedstock for the power generation. This company is not using coal or any other fossil fuel in the boiler ie they are independent power producer(IPP). So Surya Chambal has to manage the year round availability of biomass husk very effectively and very cautiously sothat continuous process of generation of electricity and power is not interrupted.

7. Supply chain of biomass in Kota

Field survey report and report of Department of Agriculture of Govt. of Rajasthan shows that, in Kota region, nearly 14 industries are using biomass (Table 1) and out of these four industries are involved in producing power using biomass as feed stock. These four biomass based power plants (IPP) in Rajasthan supplies power to the Rajasthan Power Grid. Total consumption demand in this region is approximately 6.35 Lac MT per annum.

Table 1

Biomass – Industry Demand in Kota Region		
Consumers	**Location**	**Lac MT / Annum**
DSCL	Kota	0.65
ShriramRayons	Kota	0.75
Shriram EPC	Chipabarode, Baran	1.00
Surya Chambal Power	Kota	0.75
Mahesh Edible	Tathed, Kota	0.25
Sharda Solvent	Digode, Kota	0.35
Goyal Proteins	Kasar, Kota	0.60
Shiv Agro	Kamlada, Baran	0.25
Shiv Edible	Rangpur, Kota	0.40
Ruchi Soya,	Bawri, Kota	0.20
Ruchi Soya,	Baran	0.35
Vimla Devi	Kota	0.10
Kritika Vegetable	Kasar, Kota	0.10
Oriental Power	Bhanwargarh, Baran	0.60
Total		**6.35**

Source : Report of Agriculture Department, Kota, Govt. of Rajasthan

M/S Surya Chambal Power Ltd., formally known as Chambal Power Ltd., is a 7.5 MW capacity biomass (mustard husk) based power plant, located at Rangpur Village of District Kota, about 8 kms from Kota railway station on the banks of the Chambal river. The project was started in April 2004 and the plant was commissioned and synchronized with the Rajasthan Power Grid at 33 KV on 31st March, 2006. Thus starting the supply of power through its Gopal Mill GSS situated near Kota railway station. The company is now expanding and putting up another unit of 10 MW at Khatoli village in Kota, about 100 kms from Rangpur. Its sister concerns, Sathyam Power Pvt. Ltd. is putting up a 10 MW plant at Merta Road in Nagaur district and Prakriti Power Pvt. Ltd. is putting up a 12 MW Power Plant at Gangapur city in SawaiMadhopur district .

Orient Green Power Company Private Limited (OGPL) is another Biomass power plant in Baran district of Kota region. It has an installed capacity of 8MW. The project got commissioned in October 2013.Their plant is generating power using mustard husk without using any other fossil fuel like coal etc. They have started generating power using wind energy as well. Installation and implementation of such plants is of really a great help to the people and farmers of the nearby areas.

Another major producer of energy using Biomass is DCM Shriram Rayons located in Shriram Nagar Kota Rajasthan. Their power generation capacity is 9.2 MW. They have four boilers one is working completely on coal, another on Mustard husk and other two on coal and mustard husk both. Their daily consumption of biomass husk is around 300 tonnes. The price of Biomass husk at factory gate is approx 3000Rs/MT which keeps on varying according to the availability of Biomass across the year. So roughly they purchase Biomass of thirty six crores (36 crores) in a year which is quite less if we compare it with coal (price is around 6500Rs/MT) or any other fossil fuel used for generating power. The main advantage of such plants is the concern shown by organizations for the environment and use of renewable resources like biomass for generating energy which is otherwise a waste.

8. Conclusion

In Rajasthan very little work has been done on the power generation from biomass. Through this study we have tried to find out what are the steps of a biomass supply chain and who are the key players of this chain. The problems faced by the key players in operating the supply chain and the solutions and alternatives available for implementing the supply chain. Factors like biomass product quality, handling of voluminous materials, weather related variability, localized agricultural capacity and seasonality and the demand can be taken care of by adopting new technologies and the government can take initiatives and provide financial and social help to the power generators and to the new entrepreneurs. The study will definitely help in implementation of bio-energy production projects and the researchers for further improvement.

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Annexure

Questionnaire for Employees

Dear respondent

I am conducting research under faculty of Commerce and management University of Kota, Kota, Rajasthan for the study of --- A Critical Evaluation of Operational Efficiency of Supply Chain Management of Biomass as Feed Stock to the Power Producers in Rajasthan(with special reference to Kota). Your cooperation is deeply solicitude to provide the relevant information as per the contents of the Questionnaire. Information given by you will be confidential and during analysis suitable coding will be done to conceal the respondent's identity.

1. A) Name (Optional)
   B) Company (Optional)
2. Total power generation capacity of thermal unit

- Up to 5 MW
- 6 – 50 MW
- 51 – 100 MW
- 101 – 300 MW
- Above 300 MW

Mention exact capacity ________

3. Type of boiler

- Stoker fired
- Pulverized coal fired
- Down shot fired
- Bubbling fluidized bed boilers
- Pressurized fluidized bed boilers
- Circulating fluidized bed boilers
- Cyclone fired
- Chemical recovery boilers
- Incinerators

4. What is the boiler efficiency

- Below 70.0 %
- 70.1 – 80.0 %
- 80.1 – 90.0 %
- 90.1 – 98.5 %

5. What is the thermal unit efficiency

- Below 25.0 %
- 25.1 – 30.0 %
- 30.1 – 40.0 %
- 40.1 – 45.0 %
- Above 45.0 %

6. Power generated due to biomass with respect to total power generation in the plant

- 0 – 5%
- 6 – 10%
- 11 – 30%
- 31 – 50%
- 51 – 80%
- 81 – 100%

Mention exact percentage also (if possible) ___

7. What is the biomass mix ratio in the boiler fuel?(Total should be 100)

- Coal : _________
- Biomass : _________

8. What is the Last year consumption of Biomass (in MT__?
9. What is the last year consumption of Coal (in MT) ___?
10. What is the Gross Calorific Value (GCV) of Biomass used in the boiler?
11. What is the Gross Calorific Value (GCV) of coal used in the boiler?
12. What is the Last year average GCV of Biomass
13. What is the last year average GCV of Coal
14. What is the Ash content in Biomass used in the boiler?
15. What is the Ash content in coal used in the boiler?
16. What is the Last year average Ash content of Biomass (in %age)
17. What is the last year average Ash content of Coal (in %age)
18. What is the procurement cost of biomass? Give Last year average cost (in Rs. per MT)

19. What is the procurement cost of Coal? Give Last year average cost (in Rs. per MT)

20. What are the types of Biomass vendors?

- Stockiest
- Middlemen or Agent
- Farmer

21. What are the ways of storing Biomass?

- Briquettes
- Loose - At farm land
- Silos
- Loose - At plant storage area with compacting
- Any other form (mention it) _____________

22. Type of loss of GCV during storage

  - Biomass blown away with the wind
  - Moisture addition in biomass
  - Adulteration of biomass with sand
  - Any other type of loss (mention it) ____Degradation________

23. What was average percentage loss of GCV in Biomass during storage last year?

24. What was average percentage loss of GCV in coal during storage last year?

25. What is the handling cost of biomass from storage area to boiler feed, Give Last year average cost (in Rs. per MT of biomass)

26. What are the technical / engineering difficulties faced in using biomass.

(May tick more than one)

  - Prone to catch fire
  - Deposits in super heater area
  - Large storage area due to very low bulk density
  - Loss of GCV due to degradation with time_/ Adulteration by farmers/ high transportation cost

27. What are the engineering changes done in the plant to facilitate the use of biomass (May tick more than one)

- Modification in boiler area
- Resizing of steam control unit
- Additional infrastructure to feed the biomass in the boiler

- Additional Infrastructure to handle biomass____

28. What challenges are faced by your company by the rising prices of biomass waste? (May tick more than one)

- Demand supply gap
- Heavy rains leading to crop damage
- Drought
- Entry of new consumer of biomass in the region
- All of the above
- Unavailability of the project____

29. What strategies are adopted by your organization with regards to power generation with biomass?
(May tick more than one)

- Maximize the procurement from nearest source to cater the high demand supply gap
- Market monitoring of rates to wait for the favorable price of biomass in the region
- Sub contracting of procurement activity by developing middle men in supply chain management
- Development of storage area in the region
- Increasing the in-house storage capacity within the plant.
- Development of alternate ways of storing the biomass

30. Further information, you would like to share

____

____

____

Questionnaire for Biomass Trader

Dear respondent

I am conducting research under faculty of Commerce and management University of Kota, Kota, Rajasthan for the study of --- A Critical Evaluation of Operational Efficiency of Supply Chain Management of Biomass as Feed Stock to the Power Producers in Rajasthan(with special reference to Kota). Your cooperation is deeply solicitude to provide the relevant information as per the contents of the Questionnaire. Information given by you will be confidential and during analysis suitable coding will be done to conceal the respondent's identity.

1. Name (Optional)
2. Name of Firm/company/trading unit (NA for Farmer) (Optional)
3. Type of trader
   - Individual
   - Organized
4. Locality of trader
   - Rural
   - Urban
5. What is your role in Biomass supply chain?
   - Stockiest
   - Middlemen or Agent
   - Farmer
6. What is the mode of transporting Biomass from field / storage to the power plant?
   - Tractor trolley
   - Loading truck
   - Bullock Cart
   - Any other mode __________
7. What was your last year quantity of Biomass trading (in MT) ____________?
8. How much is Sowing Area in your scope of business (in hectare) ____________?
9. How much is Storage Area in your scope of business (in hectare) ____________?
10. What is the yearly average transportation cost of Biomass per Km per MT (in Rs.)____________?
11. What is the yearly average storage cost of Biomass (in Rs.)____________?

12. Availability of Biomass (Months of the year)

a) Highest availability month of Biomass

b) Lowest availability month of Biomass

13. The prominent hardship in the business of biomass

14. Further information, you would like to share