CHAPTER 3

CHAPTER 3

ASSESSMENT OF BIOMASS SUPPLY CHAIN FOR GASIFIER OPERATION

As discussed in Chapter 1, biomass is a potential source of electricity generation. Assessment of the biomass resources of a region is important in order to establish the viability and sustainability of biomass based electricity generation for the region. The challenge in deployment of biomass based electricity generation plant is to guarantee that the right type, quality, amount and channels of procurement of biomass are available within a certain distance from the plant. The very first step in planning a biomass based plant is to identify and assess the availability of relevant biomass in the region. The assessment also helps in forecasting availability, estimating price of biomass and validating biomass based electricity generation in terms of capacity and type of conversion technology. Consideration of variability associated with biomass type, availability, characteristics, pre-processing requirements, cost and environmental impact is essential for biomass gasification as decentralized electricity generating source. This chapter presents the aspects related to utilization of biomass as feedstock for gasification based electricity generation.

3.1 Biomass type

Any plant or animal derived material is referred to as biomass [1]. Although the definition of biomass is still a topic of debate, the definition used by the United Nations Framework Convention on Climate Change (UNFCCC) is relevant here [2]:

(a) Biomass means non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by-products, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material.

(b) Biomass residues means biomass by-products, residues and waste streams from agriculture, forestry and related industries.

Biomass feedstock for gasification is principally derived from plants. Specifically, lignocellulose fraction, which is non-edible, is used. Definition of renewable biomass laid down by UNFCCC [3] is used to categorise the biomass feedstock into woody, semi-woody and biomass residue type. It is desirable to use feedstock with low moisture content to avoid the energy penalty associated with drying. Woody and semi-woody biomass are the primary choices because of their controllable moisture content. Biomass residues (leaves, grass, husk, straw, stalk, bagasse) are also promising options as feedstock [4]. However, conversion to appropriate form (pellet, powder), depending upon the energy generation technology, is needed prior to their usage.

3.2 Biomass availability

Biomass availability estimates the net productivity of biomass in the study region. Theoretical assessment is conducted based on surveys, analysing the data and assessing the results. Surveys are directed at estimating availability and assessing consumption pattern of biomass in a region. Surveys are conducted using two approaches viz. primary and secondary survey. In primary survey approach, data is collected from the direct producers of biomass i.e. farmers. In contrast, in secondary survey data is collected from secondary sources such as district administration, census reports, agricultural department and other government offices and websites. The methodology adopted for resource survey is dependent on the scale of operation being targeted. For example, a 40 kW biomass gasification based power plant may require study in one village whereas a MW scale plant may require a biomass resource survey in several districts.

Geographical Information System (GIS) is a useful spatial tool which has found application in theoretical assessment of biomass resources [5–8]. Importance of GIS is augmented by the diversity in biomass resources that can be used as energy feedstock. The diversity in the resources require a database of biomass characteristics, availability and distribution for effective planning of energy generation system utilizing the resources. GIS helps in the development of such a database which can later serve as a decision making tool for effective collection of raw material, allocation of the benefits of bioenergy and cost-benefits analysis [9–11].

As discussed in Section 3.1, there are three types of biomasses available in different ratios at different locations. Standard procedures for estimation of these biomasses is discussed in the following sections.

3.2.1 Estimation of woody and semi-woody biomass

Trees are present in all levels of a region starting from homestead to agricultural land and forests within the region. While trees, in general, yield woody biomass; small trees or shrubs yield semi-woody biomass. Biomass from all the trees in different levels can be used as feedstock for gasification based electricity generation. The annual sustainable yield of biomass from a particular tree (y_T) can be estimated by considering the area under plantation of the tree (A_T) along with productivity of the tree (Pr_T) and sustainable yield factor (F_y) using Eq. 3.1.

$$y_T = A_T \times Pr_T \times F_y \qquad \text{----3.1}$$

It is observed that some plantations are planned while some are unplanned as in the case of some shrubs yielding semi-woody biomass. Under such conditions the area under plantation (A_T) has to be modified to accommodate the share of area of unplanned plantations in different land settlements ($A_{T,Up}$). Accordingly, Eq. 3.1 is modified to incorporate the total area under a tree or shrub ($A_{T,\mathrm{total}}$) by using Eq. 3.2.

$$y_T = A_{T,total} \times Pr_T \times F_y \qquad \text{----3.2}$$

where $A_{T,total} = A_T + A_{T,Up}$

The total annual biomass yield ($y_{T,total}$) is then calculated using Eq. 3.3.

$$y_{T,total} = \sum_{i=1}^{n} [A_{T,total}(i) \times Pr_T(i) \times F_y(i)] \qquad \text{----3.3}$$

where i represents a particular tree or shrub within the total types of trees and shrubs (n) available in the region.

Estimation of woody biomass can also be done using dynamic modeling. Dynamic modeling of biomass estimation is based on biomass factor method, the allometry growth equation method and the volume source biomass method [12]. Most of these models primarily uses the diameter at breast height (D) to estimate the biomass [13]. This method, however, loses precision at larger scales due to lack in specificity for different tree species, site features and accuracy of the area measurement.

Different allometric growth equation methods have been used to develop biomass estimation equations incorporating data from published studies [13]. The equations have been modified by many researchers to adapt them to different research scenarios [12]. Models using diameter at breast height (D), tree height (H), D^2H and DH as the independent variables are also summarized in previous studies [14,15]. These models aimed at simulating a portion of or the whole plant wood biomass using a combination of the power function model, exponential model and polynomial model. Equations for estimating semi-woody biomass were also developed [16]. Site index and forest biomass variable model of the stand basal area was also developed [17]. However, it was observed that as the objective changed, the reliability of the D indicator could not conform to the needs of practical forestry estimates. A more popular estimation approach involves wood density (WD) and stand basal area (G). A combination of D, H and WD was adopted to establish a logarithmic and exponential biomass estimation model [18,19]. Fusion variable along with logarithmic model was used to estimate the biomass of the Amazon forest [20]. Structural relationships between form factor, wood density, and biomass was also studied using a variable containing D, H, WD and G in a logarithmic combined biomass model [21].

It is observed that in order to increase the accuracy of the model’s estimation of biomass, at a small scale, more number of independent variables are required [20–22]. It is also noteworthy that depending on the intended use and the actual demand, an increase in the magnitude of an independent variable of the biomass model is required [23]. Also, the definition of a forest stand is ambiguous at a large or a small scale leading to uncertainty when a model is selected [24]. This issue can be addressed by using different parameters to analyze the model. In a related study, D and H were used as independent variables to determine 8 parameters in a forest stand biomass model [25].

3.2.2 Estimation of agro-residue biomass

As discussed earlier, provisioning of decentralised electricity generation is essential in rural areas. Most rural areas have an agrarian based economy i.e. crop cultivation is the major source of livelihood in these areas. Thus, agro-residue biomass is a major source of biomass in these areas. Thus, estimation of agro-residue biomass is important for planning any biomass based energy generation for these regions. Estimation of agro-residue biomass is based on the major crops growing in the area, the area covered by each crop (A_{AR}), the biomass productivity of each of these crops (Pr_{AR}) and the residue production ratio of these crops (F_{AR}). The total annual agro-residue biomass yield ($y_{AR,total}$) is estimated using Eq. 3.4.

$$y_{AR,total} = \sum_{i=1}^{n}[A_{AR}(i) \times Pr_{AR}(i) \times F_{AR}(i)] \qquad \text{----3.4}$$

where i represents a particular crop within the total types of crops (n) available in the region.

Equations 3.3 and 3.4 gives an estimate of the total biomass yield from woody or shrub and agro-residue biomass respectively. Estimates of productivity, sustainable yield and residue production ratio are available from standard literature. However, there are uncertainties associated with the competitive uses, techniques of harvesting and threshing, and methods of collection of the biomass resources. Thus, the practically available agro-residue is different from the total yield. The practically available agro-residue is estimated by multiplying each of the Equations 3.3 and 3.4 by the resource availability factor ($F_{Rs,Av}$) which takes into account the mentioned uncertainties. Standard literature is available to accommodate the uncertainties in harvesting and collection techniques in the resource availability factor. However, there are inherent variations in the biomass consumption pattern of a particular region. Thus, assessment of biomass consumption of a region is essential to cater for the influence of competitive uses on the resource availability factor. Assessment of biomass consumption of a region is carried out by surveys. The survey centres on the direct consumers of biomass viz. households and industries utilizing the biomass. A questionnaire is designed to collect information on amount of biomass utilised as cooking fuel, fodder for livestock and raw material in industries. The resource availability factor is then attuned to incorporate the variations in the biomass consumption.

After establishing the feedstock availability, it is essential to gain an understanding on the characteristics of the available feedstock in order to establish their viable utilisation in a biomass based energy generation system. Section 3.3 below discusses the biomass characteristics influencing their utilization as feedstock in a biomass gasification based electricity generation system.

3.3 Biomass characteristics

Performance of a biomass gasification system is influenced by the biomass characteristics. Proper understanding of feedstock characteristics is essential not only in the reliable design of a biomass gasifier but also for the sustainable planning of feedstock delivery for the system.

Feedstock characteristics that have been found to have major influence on the gasification process are moisture content (MC), volatile matter (VM), ash content, organic and inorganic constituents [26]. Higher MC results in lowering of the extractable energy in the gasification plant. This is due to the fact that energy is lost in evaporation of the MC which is not recoverable. Knowledge of MC is also essential in assessing the cost involved in drying of the biomass. The ash content of biomass plays a crucial role in assessing the adaptability for gasification process. Knowledge of ash content is essential in assessing the ash handling and disposal requirements which in turn effects the economics. Also, presence of alkali metals such as potassium and halides in the ash may lead to serious agglomeration, fouling and corrosion in gasifiers. The condensable and non-condensable vapor released when a biomass is heated is the VM. The rate of production of VM depends upon the heating rate and the temperature. The rate of gasification and gas yield is determined by the conversion of fixed carbon (FC) into gases. The size of the gasifier is based on the conversion reaction of FC. Generally, the energy content and composition of biomass feedstock is described by (a) proximate analysis, (b) ultimate analysis and (c) heating values. ASTM standard E-870-82 covers the experimental determination of these properties.

Proximate analysis provides the composition of the biomass feedstock in terms of moisture (MC), volatile matter (VM), ash and fixed carbon (FC). Standard procedures followed for the determination of these individual components are shown in Table 3.1.

Table 3.1 Procedures used for proximate analysis of biomass feedstock

Sl. No.	Item	Procedure used
1	Volatile matter	ASTM E-872 for wood fuels [27]
2	Ash	ASTM D-1102 for wood fuels [28]
3	Moisture	ASTM E-871 for wood fuels [29]
4	Fixed carbon	determined by difference

Ultimate analysis provides the elemental composition of the biomass feedstock in terms of weight percentages of Carbon (C), Hydrogen (H), Nitrogen (N) and Oxygen (O). Procedures followed for the determination of the elemental composition is shown in Table 3.2.

Table 3.2 Procedures used for ultimate analysis of biomass feedstock

Sl. No.	Item	Procedure used
1	Carbon	ASTM E-777 for refuse derived fuels [30]
2	Hydrogen	ASTM E-777 for refuse derived fuels [30]
3	Nitrogen	ASTM E-778 for refuse derived fuels [31]
4	Oxygen	determined by difference

The higher heating value (HHV) of the biomass feedstock is considered in the study. HHV is essentially the amount of heat released by unit mass or volume of fuel (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C. HHV includes the latent heat of vaporization of water. ASTM E711 test method for determination of gross calorific value of refuse derived fuel by Bomb calorimeter is adopted [32].

Characterization of biomass helps in screening potential feedstock for utilization in the gasification based system. Another important aspect concerning the pre-processing of the feedstock before utilization in the gasification system is discussed below.

3.4 Biomass pre-processing

Biomass pre-processing has been reported to influence system-level efficiency of biomass gasification [33–35]. Biomass pre-processing, up to a certain degree, is required before utilization in a gasifier. Pre-processing steps depends upon the type of the biomass and the gasifier. Generally, gasifiers utilize feedstock which have a smaller and uniform size in comparison to the size collected during harvest [36]. Uniform size of the feedstock also enables a consistent feeding rate which in turn helps in maintaining the process efficiency [37]. Thus, size reduction becomes necessary. Size reduction is dependent on the type of gasifier used. For example, updraft and downdraught gasifiers require wood blocks or woodchips ranging from 8×4×4 cm to 1×0.5×0.5 cm in size. Smaller feedstock size causes flow problems, high pressure drop in the reduction zone and a large amount of dust in the gas [38]. High pressure drop causes reduction of the gas load resulting in lower temperatures and high tar production. On the other hand, larger feedstock size leads to reduced reactivity causing start-up problems and lowering of gas quality [38]. Similarly, fluidized bed gasifiers operate on feedstock with particle diameters varying between 20 – 150 mm while entrained flow gasifiers utilizes feedstock with particle diameter less than 1 mm [39]. Also, utilisation of agro-residue biomass in downdraft gasifiers involves conversion to pelletized form. Depending upon the requirement, size reduction may be carried out in two steps. In the first step, a chipper is used for primary reduction. In the second step, a hammer mill is used for secondary reduction [40].

Feedstock utilization in a gasifier is also limited by the moisture content. The maximum moisture content in biomass gasification is in the range of 20 – 30 % (wet basis) whereas for normal operation a moisture content of less than 15% is required [41]. Thus, drying is a major process of feedstock preparation for gasification. Apart from lowering the energy loss involved in evaporation, dried biomass also allows for stable temperature control within the gasifier [42]. While some biomasses can be sun dried in open others may require drying equipment like rotary dryers.

Involvement of biomass pre-processing has added implications on the overall economics of the plant utilizing them. Thus, consideration of the discussed variabilities in feedstock pre-processing is an important aspect in the planning of a biomass gasification based electricity generation system.

3.5 Biomass cost

Cost of biomass is an important parameter in the development of a biomass based decentralized electricity generation system. The cost of biomass is influenced by a number of factors including availability (which is strongly influenced by competing uses), collection cost, pre-processing cost, and transportation cost. As discussed earlier, competing uses of biomass, which vary region wise, have a considerable effect on its availability. Consequently, the cost of the biomass has to be determined based on the biomass consumption pattern of the region. Similarly, the collection cost also varies with the type of feedstock being considered. The biomass pre-processing cost also varies with the type of feedstock. The transportation cost is also vital in determining the cost of biomass. Thus, the economic analysis of a biomass gasification based electricity generation system should take into account all the above variabilities in determining the cost of biomass.

3.6 Environmental implications of utilizing biomass

All energy generation processes contribute towards greenhouse gas (GHG) emissions through all stages of construction, operation, and decommissioning. While some processes emit GHG during operation stage, like coal fired power plants, other processes, like wind and nuclear, release the majority of emissions during construction and decommissioning stage. Around 32.62 Gt of CO_2e (carbon dioxide equivalent) was produced worldwide in 2017 [43]. Of these, around 73.38% came from energy generation sector. Fig. 3.1 shows the GHG emission of different sources of energy generation throughout their lifecycle.

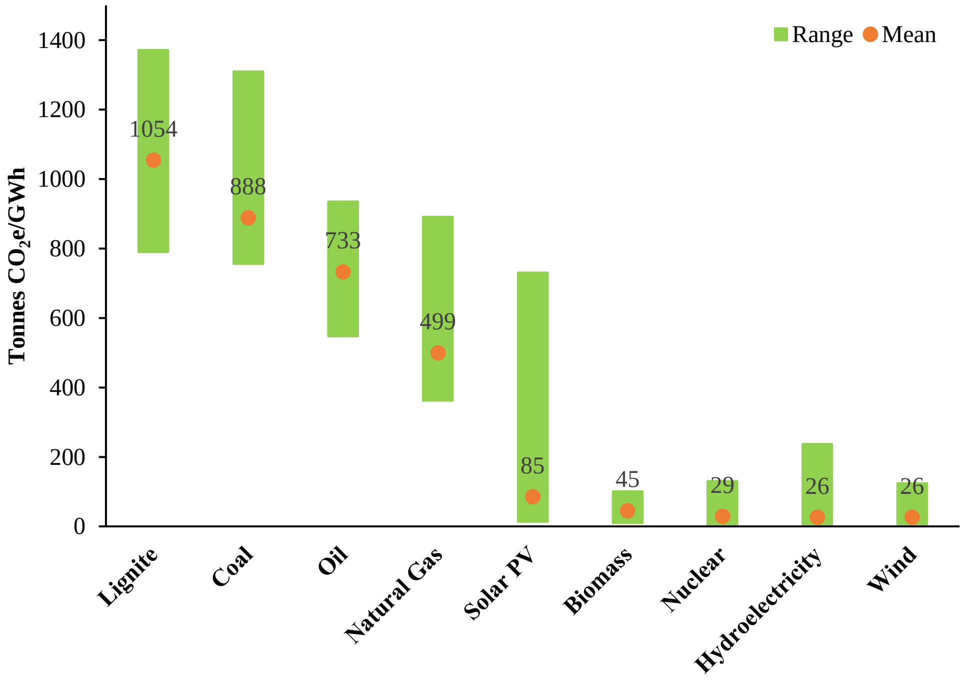

Fig. 3.1 Emissions from different sources of electricity generation
{(Source: Author's own representation based on data of Cofaigh et al [44])**}**

It may be observed that, biomass based electricity generation has a comparatively small GHG potency. Biomass grows by absorbing CO_2 from the atmosphere through photosynthesis. When the biomass is burned it releases CO_2 that the plants had absorbed earlier. This essentially makes biomass fuel "carbon-neutral". The total amount of carbon sequestered in terrestrial biomass affects the carbon content of the atmosphere. Also, as a greenhouse-gas, reduced carbon (hydrocarbon) is more harmful than oxidized carbon (oxides of carbon) [45]. The form of carbon emitted into the atmosphere depends upon the utilization of the biomass. Generally, the unutilised fraction of biomass resources is either burned in the open, buried underground or allowed to accumulate. Open burning involves poor combustion conditions and results in significant emissions of carbon in reduced form. This increases the GHG potency of the emissions. Biomass, if buried in a landfill or agricultural land, also causes emission of reduced carbon. These emissions, although delayed, have a much greater GHG potency in comparison to open burning over the long term [46]. Use of the unutilised biomass for energy generation (which involves conversion under controlled conditions) alters the timing and mix of carbon forms emitted into the atmosphere. The GHG emissions are, in turn, brought down.

Also, with reference to the Intended Nationally Determined Contributions (INDCs), biomass based energy generation presents itself as a major option for a region to fulfil its commitments. Incentivising the biomass based energy generation sector through policies and providing regulations will augment the development of the sector. Rigorous policy formulation considering the different aspects of the supply-demand chain is central to this development. In general, the policy framework should ensure the most efficient utilization of the biomass resources while providing for economic benefit to all the stakeholders in the chain. This will make the sector lucrative and attract interest from the stakeholders adding to the development of the sector.

Biomass based electricity generation is a useful approach to complement the electricity requirements of a region with minimum implications on the environment. For complementing biomass based energy generation planning for a local region viz. Sonitpur district of Assam, India, characterization of locally available biomasses was taken up. The excess biomass resource potential of the area is estimated to be around 181.7 kT/year with a power potential of nearly 27 MWe [47]. The procedures discussed in the previous sections were followed for the characterisation. The biomasses were categorized depending upon their nature into woody, semi-woody and biomass residues. The results of the analysis are summarized in Table 3.3 (a – c).

Table 3.3 (a) Characterization of locally available woody biomass

Sl. No.	Common Name	Botanical Name	Proximate Analysis (%)				Ultimate Analysis (%)				HHV (MJ/kg) (wet basis)
			MC (dry basis)	Ash (dry basis)	V M	Fixed Carbon	C	H	N	O	
1	Neem tree	*Azadirachta indica*	47.13	3.63	81.63	14.74	44.96	5.47	3.13	46.44	18.5
2	Bamboo	*Pseudopallida bambusa*	24.81	10.16	75.48	14.36	45.85	5.61	1.78	46.76	17.54
3	Cluster Fig	*Ficus golmerata*	12.96	11.57	76.51	11.91	55.76	6.94	2.92	34.38	16.53
4	Bamboo	*Bambusa jaintiana*	56.73	3.12	79.85	17.02	43.08	5.41	1.52	49.99	17.62
5	Varun	*Crateava nurvala*	45.55	14.48	68.72	16.8	36.35	5.00	1.95	56.70	15.55
6	Kadam	*Neolamarckia cadamba*	35.50	5.66	77.94	16.40	43.08	5.63	1.06	50.23	16.70
7	Potka siris	*Albizia lucidior*	27.88	6.03	77.80	16.17	43.82	5.80	1.04	49.34	16.59
8	Gul Mohar	*Delonix Regia*	33.33	10.93	61.01	28.06	43.08	5.63	1.18	50.11	16.65
9	Bhelu	*Tetramels nudiflora*	67.19	10.69	73.74	15.57	46.84	5.34	2.78	45.04	14.60
10	Grey Downy Balsam/ Garuga	*Garuga pinnata*	60.85	7.27	78.24	14.49	42.86	5.80	3.02	48.32	17.24
11	Silk Cotton Tree	*Bombax ceiba*	65.59	15.96	68.15	15.89	45.91	5.58	3.73	44.78	16.49
12	White Fig	*Ficus virens*	56.06	5.70	77.01	17.28	46.90	5.89	2.98	44.23	18.02
13	Purple Orchid	*Bauhinia purpurea L.*	44.35	4.37	77.37	18.25	49.31	6.11	3.38	41.20	16.69
14	Coral Tree	*Erythrina stricta*	71.68	7.60	71.68	20.73	45.44	5.54	3.72	45.30	17.26
15	White Teak	*Gmelina arborea*	71.19	7.72	76.12	16.16	47.74	5.98	5.98	40.30	17.98
16	Amari	*Amoora wallichi*	63.44	7.24	73.96	18.8	48.10	5.96	2.57	43.37	18.02
17	Miswak	*Salvadora persica*	50.43	7.88	78.36	13.76	45.96	5.46	3.23	45.35	15.43
18	Rain tree	*Cassia siamea Lamk*	58.29	3.63	78.67	17.70	45.63	5.94	3.90	44.53	14.50
19	Mango	*Mangifera indica*	56.77	8.84	70.78	20.37	46.96	5.68	2.87	44.49	16.94
20	Jackfruit	*Artocarpus heterophyllus*	55.41	5.11	74.61	20.28	45.66	5.67	2.22	46.45	18.24
21	Silkworm Mulberry	*Morus australis*	44.10	5.66	75.71	18.63	51.67	7.01	0.87	40.45	18.28
22	Guava	*Psidium guajava*	44.64	3.52	76.76	19.71	48.52	5.65	2.85	42.98	18.06
23	Drumstick tree	*Moringa oliefera*	82.63	8.25	70.32	21.43	41.73	5.84	2.09	50.34	15.76
24	Sugar Apple	*Annona squamosa*	61.29	3.59	75.05	21.37	48.37	5.96	4.06	41.61	17.92

Table 3.3 (b) Characterization of locally available biomass-residue

Sl. No.	Category	Common Name	Botanical Name	Proximate Analysis (%)				Ultimate Analysis (%)				HHV (MJ/kg) (wet basis)
				MC (dry basis)	Ash (dry basis)	V M	Fixed Carbon	C	H	N	O	
1	Aquatic	Water Hyacinth	*Eichhornia crassipes*	32.03	11.51	70.89	17.6	36.68	5.12	3.53	54.67	13.91
2	Leaves	Ipomea Leaves	*Ipomea carnea*	47.06	8.07	72.19	19.74	43.44	5.54	1.43	49.59	17.07
3	Leaves	Banana Leaves	*Musa bulbisiana*	25.88	9.50	71.9	18.59	43.08	5.74	1.96	49.22	19.68
4	Leaves	Coconut Leaves	*Cocos nucifera*	60.85	13.57	68.68	17.75	47.78	6.01	3.90	42.31	17.95
5	Leaves	Tall Reed Leaves	*Phragmites karka*	31.71	19.67	67.15	13.18	39.41	5.11	3.69	51.79	15.88
6	Grass	Cogon Grass	*Imperata cylindrica*	39.38	10.17	78.04	11.79	42.79	5.72	0.87	50.62	17.98
7	Grass	Reed	*Arundo Donax*	54.19	7.62	79.96	12.42	46.04	5.71	0.90	47.35	14.94
8	Husk	Rice Husk	*Oriza sativa*	11.56	17.13	63.28	19.59	42.90	6.38	4.19	46.53	12.98
9		Black Gram Husk	*Vigna mungo*	11.04	14.2	74.73	11.06	50.00	6.76	2.72	40.52	15.31
10		Mustard Husk	*Brassica nigra*	9.58	16.38	76.57	7.05	39.35	5.29	1.90	53.46	14.00
11	Straw	Rice Straw	*Oriza sativa*	10.00	11.80	74.90	13.30	49.34	5.04	0.74	44.88	14.85
12		Black Gram Straw	*Vigna mungo*	34.89	11.13	61.89	26.98	44.21	5.42	1.38	48.99	13.69
13		Green Gram Straw	*Vigna radiata*	13.30	3.65	73.53	22.82	48.92	5.89	1.89	43.30	12.49
14		Mustard Straw	*Brassica nigra*	9.43	2.98	78.57	18.45	43.70	5.93	0.42	49.95	11.23
15		Lentil Straw	*Lens culinaris*	31.19	5.53	74.61	19.87	45.13	5.13	0.64	49.10	14.54
16		Pea Straw	*Pisum sativum*	22.38	15.15	74.28	10.57	45.23	5.88	3.53	45.36	16.72
17	Bagasse	Sugarcane Bagasse	*Saccharum officinarum*	10.00	2.95	81.27	15.78	44.17	6.17	0.16	49.50	16.28
18	Stalk	Corn Stalk	*Zea mays*	70.60	3.73	75.05	21.22	44.11	5.72	1.44	48.73	14.65
19		Garlic Stalk	*Allium sativum*	31.93	26.11	61.01	12.89	27.22	4.11	1.28	67.39	11.56

Table 3.3 (c) Characterization of locally available semi-woody biomass

Sl. No.	Common Name	Botanical Name	Proximate Analysis (%)				Ultimate Analysis (%)				HHV (MJ/kg) (wet basis)
			MC (dry basis)	Ash (dry basis)	V M	Fixed Carbon	C	H	N	O	
1	Dhaincha	*Sesbania javanica*	13.58	1.84	85.63	12.53	45.24	6.06	0.56	48.14	17.18
2	Jute Stick with Fiber	*Corchorus capcularis*	15.47	9.47	76.36	14.18	44.68	5.72	2.85	46.75	19.26
3	Jute Stick without Fiber	*Corchorus capcularis*	8.59	1.63	82.24	16.13	46.34	5.96	0.18	47.52	17.98
4	Ipomoea Stem	*Ipomoea carnea*	20.45	9.80	75.70	14.49	43.11	5.18	3.49	48.22	16.32
5	Indian Tamarisk	*Tamarix indica*	13.71	6.82	78.58	14.60	47.38	5.80	3.03	43.79	17.17
6	Castor	*Ricinus communis*	73.34	6.85	81.37	11.77	41.58	5.68	0.34	52.4	17.25
7	Tall Reed	*Phragmites karka*	31.71	19.67	67.15	13.18	45.62	5.68	2.54	46.16	15.98

Fig. 3.2 shows the variations in the different characteristics of the biomasses of the region. It is observed that the MC varies in the range of 8.59 – 82.63, ash content in the range of 1.63 – 26.11, VM in the range of 61.01 – 85.63, FC in the range of 7.05 – 28.06, C in the range of 27.22 – 55.76, H in the range of 4.11 – 7.01, N in the range 0.16 – 5.98, O in the range of 34.38 – 67.39 and HHV in the range of 11.23 – 19.68.

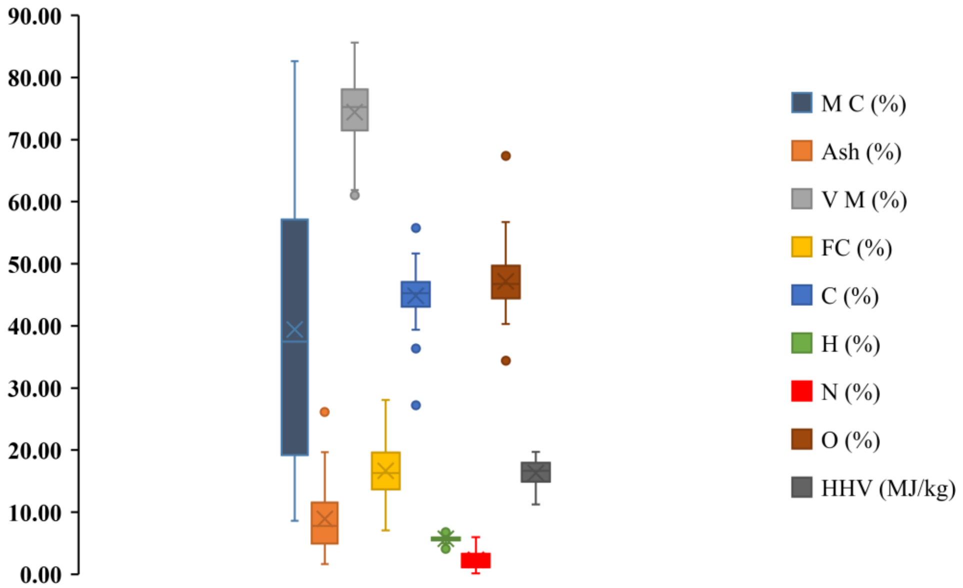

Fig. 3.2 Range of variations in the biomass characteristics

It is observed that there is variability in the characteristics of the biomasses. The coefficient of variation in the case of MC, Ash, VM, FC, C, H, N, O and HHV is 0.55, 0.60, 0.07, 0.25, 0.10, 0.08, 0.58, 0.11 and 0.12 respectively. Here it is worth mentioning that there also exists spatial and temporal variation in the biomass resources. Thus, utilization of the biomass in energy generation systems requires further analysis in terms of performance of the conversion systems utilizing them and also the associated economics.

3.7 Summary

A standard methodology could be developed for considering variabilities associated with aspects of the biomass supply chain viz. availability, pre-processing requirements, cost and environmental impact for use of biomass as a DEG source. However, there is dependency of the conversion process of a biomass gasifier based electricity generation system on the characteristics of the biomass feedstock. Thus, there is a requirement to analyze the performance of a biomass gasifier utilizing an array of biomass feedstock. The approach adopted to assess the gasification performance with variations in the feedstock characteristics is discussed in the following Chapter.

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