



## RESEARCH ARTICLE

### DENDRO BIOMASS RESOURCES FOR SOLID AND LIQUID FUEL GENERATION – OPPORTUNITIES AND CHALLENGES

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#### Abstract

*Biomass contributes nearly 10-14% of the global energy supply and is fourth largest after coal, petroleum and natural gas. The main utility of biomass has been directed towards direct combustion to generate steam based power in a decentralized approach. This biomass can very well be converted to liquid fuels like ethanol, butanol, biodiesel and biogas (Tuli, 2013). The demand for energy across the world is increasing steadily which resulted in fast depletion of petroleum resources and necessitated an increased interest in alternate fuels particularly on liquid transportation fuels (Wyman, 2007; Lynd, 2008). The predominant alternate fuels gaining significant attention across the world are biodiesel and bio petrol (Ethanol). The technologies for generating biodiesel from wide range of vegetable oils have been very well witnessed but for want of adequate and enough raw material resources, the achievement in biodiesel production is still dismally modest. Similarly bioethanol from ligno cellulosic biomass is considered as one of the alternate and easily adaptable fuel but due to availability of raw material and the associated cost effective processing technology limit the production and availability of bioethanol as well (Sukumaran et al, 2009).*

In India, the requirement of energy is steadily increasing due to progressive development in science and technology coupled with urbanization and the rural infrastructure development. It has been estimated that India has an installed capacity of 223 GW of energy and it will reach 400 GW in the year 2030. Similarly, 78% of the current crude oil requirement is being imported which has taken heavy toll of the country's exchequer. These energy resources besides massive imports have contributed significantly towards accumulation of both gaseous and particulate pollutants thereby contaminate the environment. This has compelled development of alternate source of energy which are safe and environmentally viable. Under such circumstances, India needs to develop sustainable and decentralized energy

planning process for which the role of biomass based energy generation both for liquid and solid energy generation is very significant. Though the current estimates indicated that biomass is available in surplus, but its quality and the availability in a decentralized farmlands and its value addition to other agricultural utility detract their availability to biofuel utility.

Hence the biomass derived from trees which are pronounced as dendro biomass will have an excellent role to play in biofuel generation due to their quality and their bulk availability. Considering the dendro biomass potential, the research group at Tamil Nadu Agricultural University has established a viable value chain approach to augment the Production to Consumption System (PCS) in Biofuel production process.

#### A. Opportunities and Significance

In India the biomass provides fuel for about 32% of the total primary energy consumed and caters to almost 70% of the population. Wood based dendro biomass has a significant and critical role not only in enhancing the biomass availability but also extending the scope for both solid and liquid fuel generation. The woody biomass are rich in carbon, hydrogen and oxygen and the wood resources have been classified as high cellulose, high lignin and low cellulose based on wood quality. Similarly the wood biomass resources are classified as dense wood, moderate and soft wood which may be suitable for meeting the demands of both solid and liquid fuel generation. The dendro biomass due to their high calorific value is directly deployed in combustion and gasification based biomass power generation. The potential species deployed in biomass power generation industry with their wood quality estimates are furnished in table 1.

**Table 1. Thermo chemical properties of species amenable for biomass power generation**

S. No.	Species	Specific gravity	Volatile matter (%)	Ash content (%)	Fixed carbon (%)	Calorific value (kcal/kg)	Fuel value index	Ash deformation temperature (°C)	Ash fusion temperature (°C)	Lignin content (%)	Heating value (MJ/kg)
1	Acacia holosericea	0.54	66.53	4.58*	21.25	3692	27.29	1043.33	1080.00	29.67	27.84
2	Acacia auriculiformis	0.49	66.83	3.50	21.00	3557	30.23	1080.00	1140.00	30.00	28.45
3	Anacardium occidentale	0.50	66.33	4.07	21.60	3441	28.16	1100.00	1180.00	30.00	28.38
4	Bambusa vulgaris	0.54	66.21	3.71	22.92	4130	109.86	1130.00	1210.00	33.17	30.57
5	Bambusa bambos	0.56	66.66	2.92	23.08	4150	115.51	1136.67*	1205.00	32.00	30.59
6	Casuarina equisetifolia	0.58*	67.62	2.33	23.38*	4593*	251.65*	1156.67*	1230.33*	34.33*	31.35*
7	Cassia siamea	0.48	65.87	4.47*	21.17	3462	25.15	1050.00	1110.00	28.00	28.18
8	Caesalpinia pulcherima	0.43	66.00	4.38	22.12	3479	23.32	1080.00	1120.00	28.17	28.21

9	Dalbergia sissoo	0.58 *	66.4 3	2.8 8	23.75 *	4314 *	236.81 *	1136.67 *	1230. 00*	33.25 *	30.81 *
10	Eucalyptus tereticornis	0.61 *	67.00	2.50	23.85 *	4614 *	240.69 *	1150.00*	1241. 67*	33.67 *	31.02 *
11	Gliricidia sepium	0.44	65.50	4.75 *	20.5 8	3913	21.31	1083.33	1136. 67	29.0 0	27.6 1
12	Lannea coromandelic a	0.45	66.33	4.37	21.3 0	3812	23.29	1060.00	1136. 67	27.0 0	27.8 5
13	Leucaena leucocephala	0.62 *	68.08 *	1.75	24.33 *	4552 *	265.68 *	1173.33*	1273. 33*	34.42 *	31.50 *
14	Prosopis juliflora	0.78 *	68.17 *	1.48	24.88 *	4860 *	303.72 *	1220.00*	1290. 00*	35.17 *	31.69 *
15	Simarouba glauca	0.55	65.83	4.97 *	21.7 0	3781	31.48	1056.67	1196. 67	29.3 3	28.0 2
	<b>Mean</b>	<b>0.54</b>	<b>66.62</b>	<b>3.51</b>	<b>22.4 6</b>	<b>4023. 33</b>	<b>121.62</b>	<b>1110.44</b>	<b>1178. 36</b>	<b>30.6 1</b>	<b>29.4 7</b>
	<b>SEd</b>	<b>0.01 8</b>	<b>0.83</b>	<b>0.84</b>	<b>0.64</b>	<b>64.51</b>	<b>63.82</b>	<b>19.01</b>	<b>24.55</b>	<b>1.48</b>	<b>0.48</b>
	<b>CD(0.05)</b>	<b>0.03 6</b>	<b>1.19</b>	<b>0.91</b>	<b>0.75 0</b>	<b>131.7 5</b>	<b>85.34</b>	<b>25.83</b>	<b>49.13</b>	<b>2.57</b>	<b>1.15</b>

Similarly wood biomass also known for their lignocellulosic presence and the current research group has identified and developed improved varieties for high cellulose and low lignin in several wood species. The ligno cellulosic species suitable for ethanol and butanol production are furnished in table 2.

**Table 2. Wood Quality analysis of tree species amenable for biofuel production**

S. No.	Species	Bulk density (Kg/m <sup>3</sup> )	Basic Density (Kg/m <sup>3</sup> )	Holo cellulose (%)	Acid insoluble lignin (%)	Pulp yield (%)
1	Acrocarpus fraxinifolius	289.00	624.00	74.20	24.71	48.40
2	Acacia auriculiformis	330.00	580.00	68.47	27.26	48.70
3	Albizia falcata	288.00	530.00	67.29	26.36	48.60
4	Anthocephalus cadamba	180.00	385.00	68.82	26.33	48.50
5	Bambusa balcooa	214.00	487.94	67.60	22.40	44.69
6	Bambusa vulgaris	198.00	500.72	63.50	22.10	42.79
7	Cassia siamea	250.00	530.00	67.73	28.31	45.50
8	Chukrasia tabularis	257.33	467.11	73.68	26.14	46.50
9	Dalbergia sissoo	286.00	610.00	69.35	25.62	49.40
10	Erythrina spp.	220.00	430.00	72.00	24.00	42.00
11	Lannea coramandalica	220.00	480.00	74.00	24.00	43.00
12	Leucaena leucocephala	250.00	546.00	74.14	24.32	49.50

1 3	Melia dubia	280.00	286.00	74.00	27.75	50.50
1 4	Melia composita	260.00	510.00	78.00	22.0	48.50
1 5	Populus deltoides	179.33	380.03	74.15	22.87	48.00
1 6	Sweitenia macrophylla	270.25	520.00	69.54	26.39	41.89
1 7	Thespesia populnea	253.00	464.77	71.91	26.35	48.00
1 8	Gmelina arborea	258.00	486.00	69.16	26.67	49.10
1 9	Casuarina	232.00	495.00	75.83	26.46	48.50
2 0	Eucalyptus	240.00	540.00	74.36	26.73	44.20

## B. Sources of Dendro biomass

Raw materials that can be used to produce biomass fuels are widely available across the country and come from a large number of different sources, and in a wide variety of forms. All of these forms can be used for fuel production purposes, however not all energy conversion technologies are suitable for all forms of biomass. The biomass sources from forestry sector alone are furnished.

### a. Wood and wood residues

Wood consists of wood and other products such as bark and sawdust which have had no chemical treatments or finishes applied. Wood may be obtained from a number of sources which may influence its physical and chemical characteristics. The lignocellulosic wood is suitable for a range of energy applications. It can be burned for heat and/or power at a range of scales. New 'second generation' technologies are being developed which are capable of producing a range of liquid or gaseous transport bio fuels from ligno cellulosic wood.

#### 1. Bark

Bark may be removed from saw logs and available as a residue from wood processing. Bark typically contains high levels of minerals and consequently is prone to give high levels of ash and slogging in combustion systems. It may, however, be a suitable fuel for generating process heat close to where it is produced, such as for firing drying kilns at a sawmill. Minerals will be retained in the ash and consequently this may be used as a soil fertilizer.

#### 2. Logs

Small Round Wood (SRW) may simply be cut into logs. This may be done in the plantation for ease of extraction and handling and to assist drying, and involve delimbing and cutting into logs of typically 2-3 m in length.

#### 3. Sawdust

Sawdust is typically available as a co-product of wood processing or manufacturing. It may be of high moisture content, e.g. from cutting green wood in sawmill, or very dry from furniture manufacturing. It may have a bulk density only 30% of that of the solid wood and so, even if very dry, has a very low energy density. It does, however, present an extremely large surface area to volume ratio and is suitable for blowing into some combustion or gasification systems. Sawdust, especially dry sawdust, is particularly suitable for processing into pellets

#### 4. Wood chips

Although logs can be stored and transported conveniently when stacked, and the ease of

air passage through a log pile allows good drying, they may not always be the most convenient form for automated handling and feeding. Also, the relatively small surface area to volume ratio is not ideal for efficient combustion or gasification. Wood chips can form a much more uniform fuel that can flow and can be fed to a boiler, gasifier or other conversion system as a steady flow using an auger feed or a conveyor. With a large surface area to volume ratio they can also be burned very efficiently. Wood chips may have a bulk energy density of about 50% of that of the solid wood.

5. Wood pellets and briquettes

Wood pellets are made from dry sawdust compressed under high pressure and extruded through a die. They may include a low level of added binder, such as starch, but many use nothing other than steam. Wood pellets should be dry, clean, mechanically robust and have an ash content defined by the appropriate standard to which they have been made, which may also define other contaminants such as chlorine content. Briquettes are similar to wood pellets, but physically larger. Sizes vary but briquettes can vary in diameter from around 50 mm to 100 mm+. Briquettes are usually between 60 mm and 150 mm in length. They can offer a cleaner, more consistent alternative to firewood logs, offering higher energy density and steady combustion

6. Wood from plantations

This includes wood from private and state owned forest and plantations. As harvested, wood will be at a range of moisture content, and of a variety of physical shapes and sizes. In addition to harvesting, some level of pre-processing is likely to be required. Transport and storage will also be necessary.

**Wood processing industry co-products**

The wood processing industries, such as sawmills and timber merchants are also a source of virgin wood in the form of off cuts, bark and sawdust. Many transport, pre-processing and storage issues may be similar to those for plantation products, however the material obtained is likely to be in different forms from plantation or arboricultural products.

There are likely to be a number of different output streams with different characteristics:

1. Sawmill off cuts may include a high proportion of bark.
2. Some material may have been kiln dried to extremely low moisture content making it potentially very suitable for wood pellet manufacturing or blending with material at higher moisture content.
3. There may be sawdust at a range of moisture content from different stages of processing, and again very dry sawdust from kiln dried timber may be very suitable for wood pellet manufacture.

**C. Challenges**

1. Biomass availability

In India, it has been estimated that 500 million tonnes of biomass is generated annually and of which 120 – 150 million tonnes is available for biomass utility. However several biomass industries are under threat due to non availability of biomass which indicated a wider gap between the demand and the actual viability. All agricultural residues viz., forest and plant biomass are classified as lignocellulosic materials and are rich in carbon, hydrogen and oxygen. These biomass resources are abundantly available with low cost in India. However these resources are available in small and medium farm holdings coupled with diverse crop pattern which resulted in problems in the entire supply chain process. The biomass collection at the scale required and transportation of low bulk density biomass to a single large plant site would all make the feed stock availability not only difficult but also expensive for viability of large scale biomass biofuel refineries.

2. Competition from other industries

Though the biomass is available in plenty in the country but due to competition from other industries its conversion to biofuel industry is a major bottle neck. Because several times the biomass is converted into various value added products like cattle feed stock, biomass



compost etc which made them non available to the industries. The competition between industrial utility and cattle feed utilization lead to feed stock shortage. Hence there is a need to develop non food and feed quality raw material resources which may be amenable for biofuel generation. Under such circumstances wood based biomass resources will play an excellent role in meeting the biomass resources on a large scale due to their increased density, higher yield, non seasonal and their suitability as a ligno cellulosic material. The wood based ligno cellulosic biomass have to be characterized for their quality towards high cellulose and low lignin for liquid fuel generation and moderate cellulose with high lignin for solid fuel based power generation.

3. Bioprocessing technology

The woody biomass available can be used directly or woody biomass can be generated in the form of energy plantation through agro and farm forestry. However the major challenge in woody biomass is the technologies for pre treatment, fractionation of lignocellulosic biomass to cellulose, lignin and hemicellulose and their further conversion into sugars and finally into an ethanol coupled with the other value added products. The overall technology involved multiple steps which need to be standardized for economical viability and ecological sustainability.

4. Lack of organized plantations

Establishment of exclusive biofuel plantation is yet another challenge faced by various stakeholders. The plantations available currently are sure that they are ligno cellulosic but they are used by multifarious industrial sector like pulp, paper, packing case, plywood, veneers etc. and limit the availability of biomass resources to biofuel industries. Hence development of exclusive biofuel plantations both for solid and liquid energy generation is very vital towards sustaining the process.

5. Non availability of quality raw material

The quality of currently available biomass is widely questioned due to multifarious feed stock. The quality in terms of cellulose, hemicellulose and lignin vary with species to species and increase or reduction of 1% in the quality parameters will have a significant impact in the processing side. Hence development of quality raw material is very vital.

6. Uncertain supply chain

One of the major challenges in biomass availability is the existence of unorganized and multipartite supply chain system. This unorganized supply chain system play a key role in biomass availability. The supply chain involves wide range of players with several middlemen and trader. Because of this multi-partite supply chain, variation in pricing system and marketing pattern delimit the availability of biomass resources for biofuel industries. This unorganized supply chain needs to be changed with organized institutional mechanism to create a platform for a sustained supply of dendro biomass resources. The alternate utility of biomass resources for other wood based industry is also a major problem in the supply chain process which needs to be addressed.

7. Lack of price supportive system

For sustainability and commercial viability of dendro biomass resources, price supportive system is very critical both for promotion and commercial utilization. Unfortunately there is no price supportive mechanism for the ligno cellulosic biomass both for solid and liquid fuel generation. Due to lack of price supportive system and multi-partite supply chain, the price of ligno cellulosic biomass is highly variable and is the major challenge faced by the biofuel industries.

8. Policy support mechanism

The promotion of biomass for biofuel utility demand a strong policy intervention towards incentives for biofuel plantation development programme coupled with assured and competitive price supportive system. This has to be addressed in detail inviting all

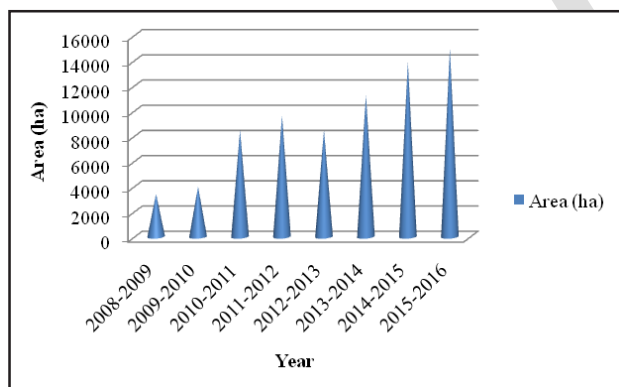
stakeholders to draw a workable policy support.

#### Status of dendro biomass feed stock availability

The dendro biomass resources has a potential share in biofuel utility both for solid and liquid fuel generation. These dendro biomass resources can act as an excellent feed stock and with a planned resource planning, the availability can be matched with the demand for the raw material. For this purpose, it is estimated that one hectare of an energy plantation on an average is able to generate 100 tonnes of ligno cellulosic biomass suitable for biofuel utility. If this target is planned in a decentralized approach, the demand for raw material can easily be met through organized energy plantation development programme. The current research group has estimated the availability of nearly 74 million tonnes of ligno cellulosic biomass which can be deployed for the biofuel industries.

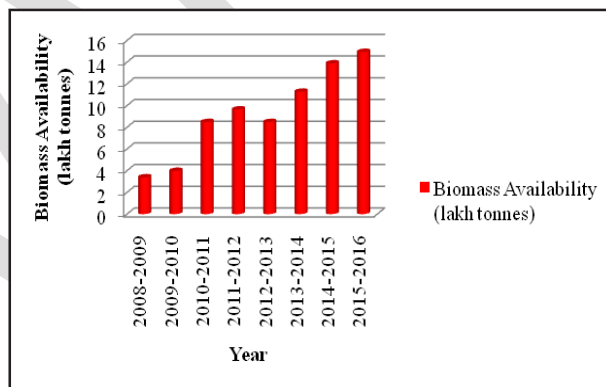
Among 20 different tree species of ligno cellulosic biomass utility, only five species have been estimated for their biomass availability. These five species include Casuarina, Eucalyptus, Bamboos, Ailanthus & Melia and the first four species have been grouped under one category and it is estimated that an area of over 74000 ha is now available which has the biomass yield potential of over 74 million tonnes and indicated greater scope for their deployment in biofuel industry (Fig.1a and 1b; plate 1). These biomass resources have excellent wood quality with high cellulose and low to moderate lignin content. With the development of suitable and cost effective processing technology, these biomass resources can be directly used for power generation through combustion technology and into ethanol through ligno cellulosic conversion technology.

Fig 1a. Status of lignocellulosic



biomass plantations in Tamil Nadu

Fig 1b. Status of lignocellulosic



biomass availability in Tamil Nadu

### Plate 1. Lignocellulosic Biomass Plantations



#### *Melia dubia*

Variety : Melia MTP 26  
Basic Density : 286.00 Kg/m<sup>3</sup>  
Hollocellulose : 74.00 %  
Lignin : 27.74 %

#### *Anthocephalus cadamba*

Variety : Kadam AC 13  
Basic Density : 385.00 Kg/m<sup>3</sup>  
Hollocellulose : 68.82 %  
Lignin : 26.33 %



#### *Casuarina*

Variety : Casuarina MTP 2  
Basic Density : 495.00 Kg/m<sup>3</sup>  
Hollocellulose : 75.83 %  
Lignin : 26.46 %

#### *Eucalyptus*

Variety : Eucalyptus EC 48  
Basic Density : 540.00 Kg/m<sup>3</sup>  
Hollocellulose : 74.36 %  
Lignin : 26.73 %





Another major breakthrough in biomass improvement is the identification of *Melia dubia* as the potential lignocellulosic biomass species due to its higher cellulose and low lignin content. The development of high yielding and short rotation clone (Parthiban and Seenivasan, 2016) in the species has attracted its deployment in biofuel utility. This species is one of the fast growing tree amenable for harvest in 2 years and has a potential to yield the biomass volume of 100 tonnes / ha. This species has been planted in an area of over 900 ha and has a potential to yield 0.9 million tonnes of lignocellulosic biomass at present (Fig 2a, 2b). This biomass exhibited cellulosic pulp yield of over 50% coupled with low lignin content and extended greater scope for its adoption in liquid fuel generation particularly for ethanol production.

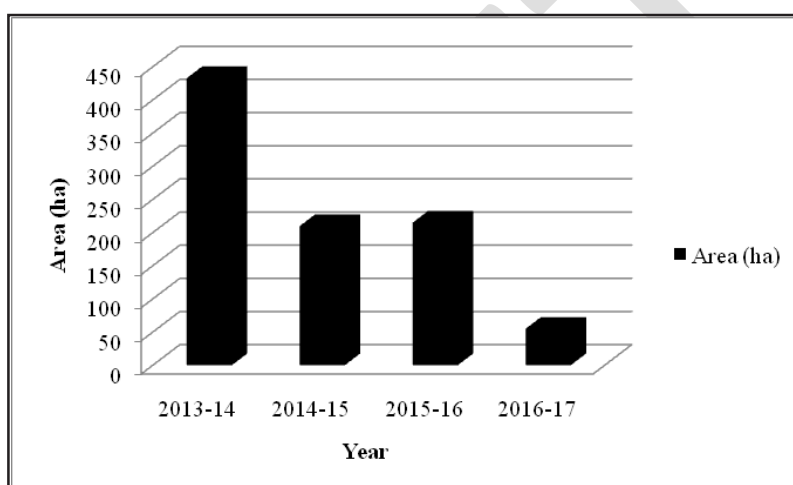


Fig 2a. Status of Melia based lignocellulosic biomass plantations in Tamil Nadu

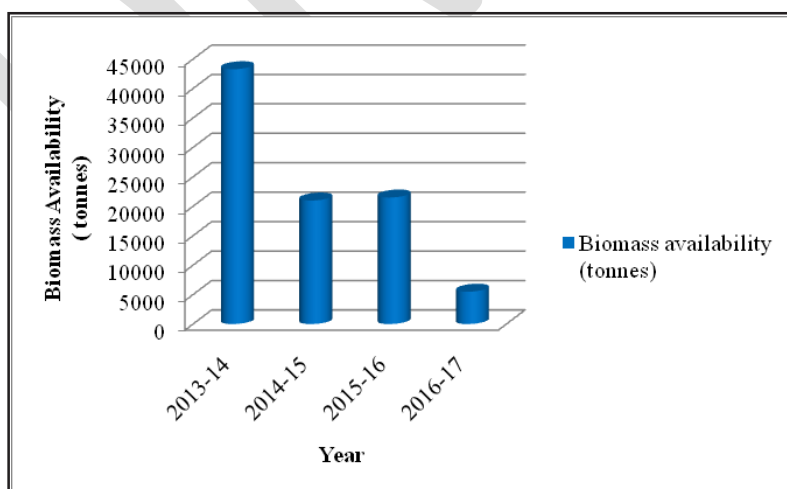


Fig 2b. Status of Melia based lignocellulosic biomass availability in Tamil Nadu

### E. Strategies to augment the biomass resources

Forests in general and forest biomass in particular have enormous role in biomass sector leading to the production of solid and liquid energy. The country's forest area is legally closed for any production oriented purposes which resulted in the wood based industries deriving raw material predominantly from natural forests till the recent past. These wood based industries have started generating their own raw material resources by establishing exclusive industrial wood plantations through a consortium mode. Similar approach can be established to augment the biomass resources to cater the feed stock needs of biomass and biofuel industries. The following strategies will help to improve the situation in biomass resource availability.

#### 1. Development of exclusive biomass energy plantations

Since the government of India has mandated blending 20% biofuels in transport sector from 2017 onwards and promotes decentralized energy planning process through biomass, it is very ideal to develop exclusive energy plantations suitable for liquid as well as solid energy generation. The Forest College and Research Institute of Tamil Nadu Agricultural University has identified the following tree species suitable for varied energy utility (Table 3)

**Table 3. Potential dendro biomass species for biofuel utility**

S.No	Energy Utility	Species	Product	Quality
1.	Biodiesel	Jatropha curcas Pongamia pinnata Madhwa latifolia Callophyllum inophyllum	Seed Oil	1. High oil content associated with the fatty acid profile 2. 30% and above
2.	Ethanol	Melia dubia Thespesia populenea Eucalyptus spp. Casuarina spp. Populars Lannea coromandelica Bamboos Leucaena leucocephala	Wood	1. High cellulose and low lignin 2. 48% and above
3.	Power generation through gasification	Acacia holloserecia Prosopis juliflora Gliricidia sepium	Wood	1. High calorific value 2. Wood thickness of 1" – 2"
4.	Power generation through combustion	Prosopis juliflora Dalbergia sissoo Leucaena leucocephala Eucalyptus tereticornis Acacias Spp.	Wood	High calorific value 4000 - 5000 kg cal.

		Cassia Spp.		
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## 2. Development of High Yielding Short rotation energy plantations

One of the major strategies in promotion of biomass energy plantation is the development of High Yielding Short Rotation varieties preferably the clone based energy plantations. For this purpose, the Tamil Nadu Agricultural University has developed wide range of energy species which are amenable for high yielding and short rotation. The major species and the improved cultures within the species along with their potential yield are furnished in Table 4.

**Table 4. High Yielding Short Rotation Clones suitable for Biofuel Utility**

Energy Species	Variety	Spacing (in feet)	Density / Acre	Period (In years)	Average Yield (Kgs)	Yield / ha (tonnes)
Eucalyptus	MTP 1	6x6 ft	1,200	3	40	36.00
Casuarina	MTP 2	5x5 ft	1,770	3	38	67.00
Subabul	FCRI LL15	4x4 ft	2,200	3	32	70.00
Dalbergia	MTPDS18	6x6 ft	1,200	3	40	48.00
Melia	Melia CL26	6x6 ft	1,200	2	50	60.00

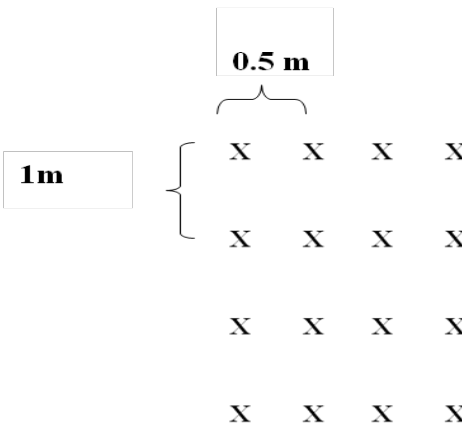
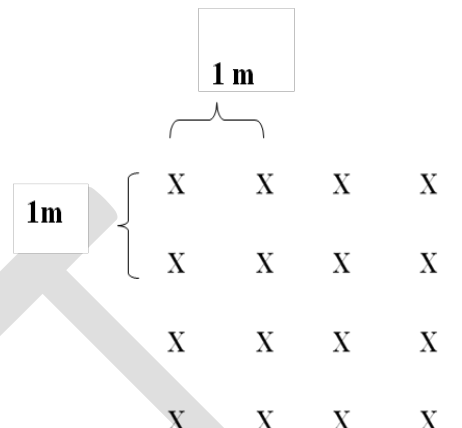
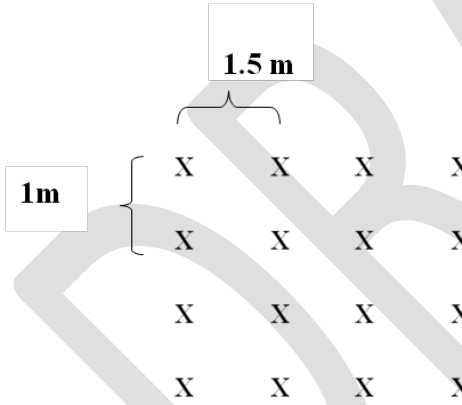
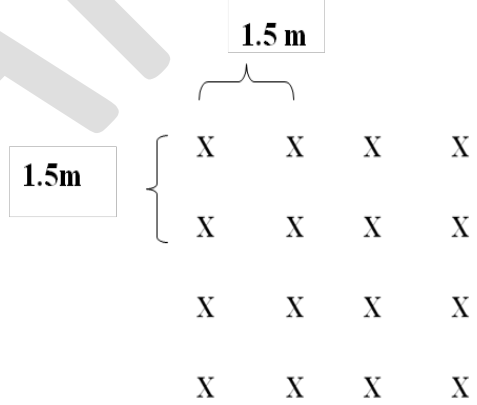
## 3. Dendro Energy models

The promotion of biomass resources for energy generation both for solid and liquid energy demands organized models for intensive promotion. The TNAU has developed various models which are discussed below.

### a. High Density Short Rotation Model

This High Density Short Rotation (HDSR) Plantation models are vary from species to species and the general model adopted for various dendro energy species are depicted below in order to get sustained yield to meet the raw material requirement of biofuel industries (Fig. 3 and Fig.4).

**Fig 3. High Density Energy Models**

Model-1	Model-2
	
Model-3	Model-4
	
Spacing	1m x 0.5m, 1m x1m, 1m x1.5m, 1.5m x 5m
Number of plants ha-1	20 000, 10 000, 6 666 and 4 444

(Durairasu and Parthibal et al, 2013)

#### **b. Hybrid Tree Model**

This model incorporates two different species in the same unit of land to auger the productivity and income by production of industrial wood for two different industries. Accordingly, Cauarina + Melia, Melia + Glyricidia, Melia + Subabul, Melia + Ceasalpineia etc., are recommended for hybrid tree model. Melia can be utilized for pulp and plywood industries and other trees can be profitably grown for biomass power.

#### c. Monoclonal Model

High yielding clones of various species like Casuarina (MTP 1 & 2), Eucalyptus (ITC 3, 7, 413 and TNAU 48), Melia (MTP 1, 2 and 7), Subabul (FCRI LL15),

*Dalbergia sissoo* (MTPDS 18) and *Glyricidia* (FCRI 1-10) can be raised as high density monoclonal plantations. These plantations with intensive and precision silviculture management could be harvested on a sustainable basis either annually or once in two years depending on the species.

#### d. Polyclonal Model

Different clones in the same species can be planted as a mixed polyclonal model either with alternate rows / blocks of five to ten rows / paired row model etc. For this purpose, single species with multi clonal incorporation could be made for increased productivity and profitability. The medium to large land holdings are amenable for such poly clonal model.

#### e. Sporadic model

This model incorporates sporadic distribution of trees. The small land holders cannot afford monocropping of tree crops and hence this model is suggested using sporadic distribution of biomass trees like Acacia, Melia, Eucalyptus and Casuarina.

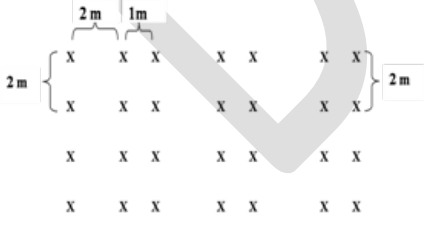
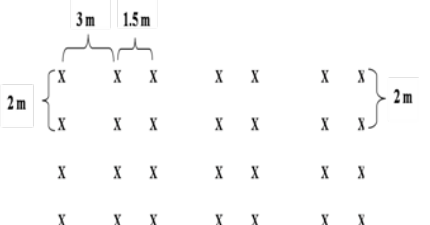
#### f. Linear model

This model incorporates linear planatation of single species of Eucalyptus / Casuarina / Albizia / Subabul / Melia / *Glyricidia* / *Cassia siamea* etc., in the National and State Highways, along the railway lines and community lands. This will ensure availability of raw material on a large stretches of land which are currently unutilized.

#### g. Paired row model

This model ensures integration of single or two species in a paired row system. For every one pair an alternate single row can be established which will increase the productivity. This model is suitable for small and medium land holdings.

Fig 4. Paired Row Energy Models

Model-1	Model-2
	
Spacing	2 m x 2 m and 1 m & 3 m x 1.5 m and 1.5
Number of plants ha-1	2 900 & 2 250

(Durairasu and Parthibal et al, 2013)



#### 4. Approaches for augmenting dendro biomass resources

The dendro biomass energy resources can be augmented by establishing adequate linkages between the stakeholders to complete the entire value chain process. For this purpose, the Tamil Nadu Agricultural University has conceived and implemented a consortia mode biomass energy plantation model through bi, tri and quad partite model which are indicated in figure 5, 6 & 7 and these model can be approached to generate adequate biomass resources both through captive as well as agroforestry based energy farming.

##### a. Bi-Partite Model

This model incorporates two stakeholders' viz., biofuel industries and farmers (Fig.5). Under this system, the biofuel industry can supply quality planting materials of energy trees, site specific technical guidelines and periodical monitoring of various stages of tree growth by their scientific staff members. This besides, the biomass industry can assure a minimum support price of wood at farm site at the time of agreement. In case, if the market price exceeds the agreement price at the time of harvest or lower; in both the cases the biofuel industry should assure higher price to the grower. The biomass industry also assures transportation at its own cost from the farm land to the biofuel industry. The farmer assures to follow the guidelines prescribed by biofuel industry and the growers are abide by the rules and purchase regulations of biofuel industry and supply the harvested produce to the firm as per the agreement.

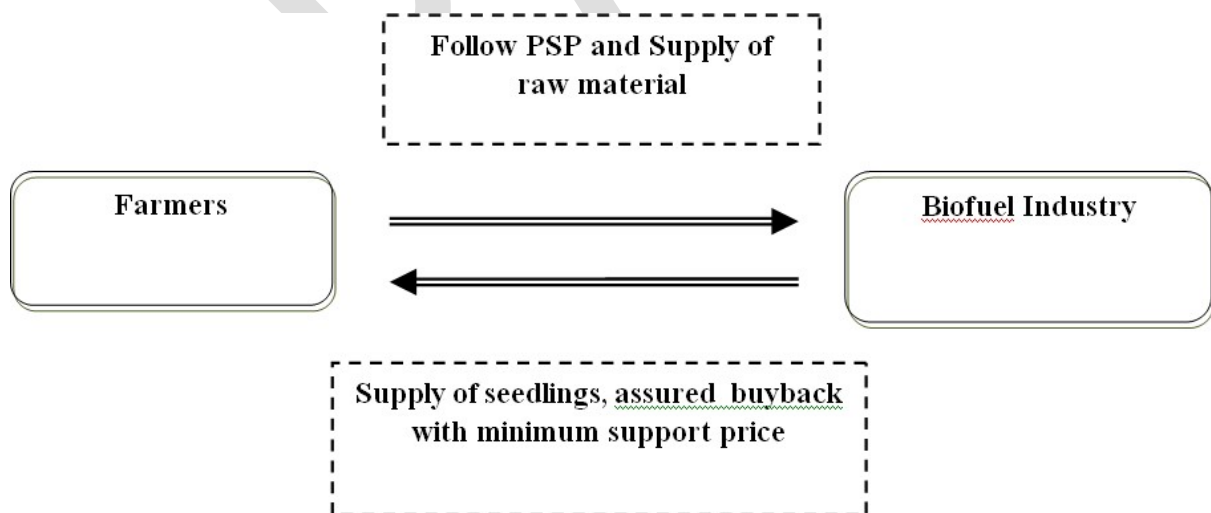


Fig. 5. Bi-partite Model Energy Farming

### b. Tri-partite Model

This model incorporates industry, growers and research institute. Under this system, the industry supplies quality planting material at subsidized rate and assures minimum support price or the prevailing market price whichever is higher. The farmer supplies the material to the contracting industry and the research institute advice site specific technology. The varieties already developed by the research institute are mass multiplied through its agri business incubators (ABI) distributed across the state and supplied to the contracting farmers at subsidized and affordable prices (Fig.6).

#### Supply of raw material

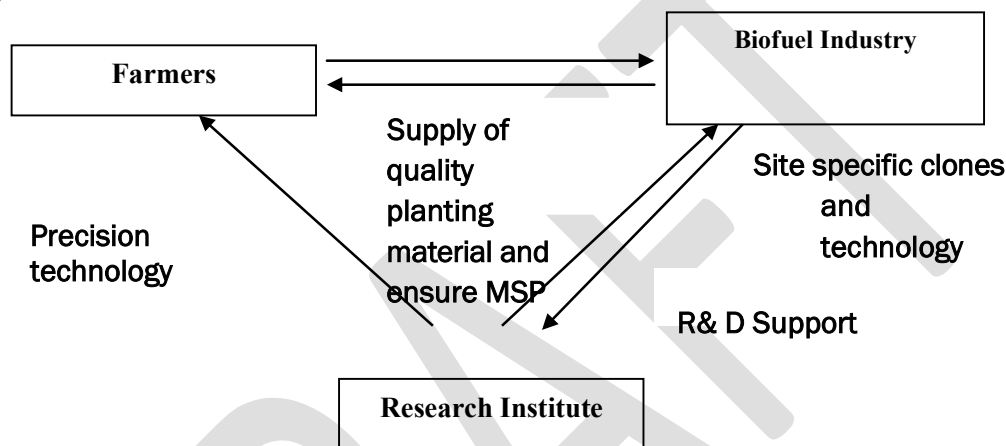


Fig 6. Tri-partite Model Energy Farming

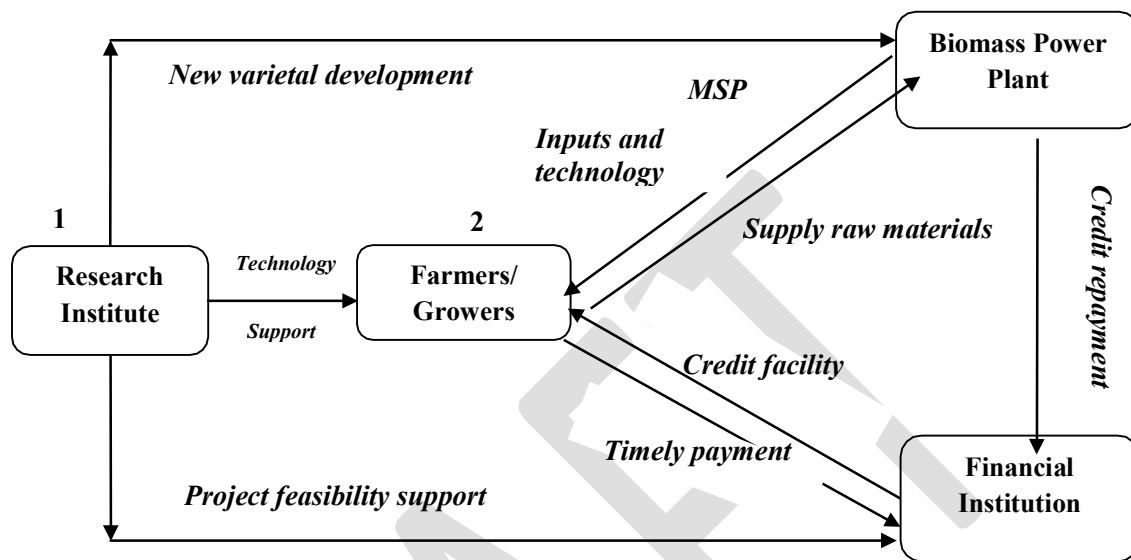
### c. Quad-partite Model

This system is similar to tri-partite model barring the involvement of financial institution. (Fig.7). Financial institutions provide credit facilities to the growers. For credit facilities, a simple interest rate at 9 per cent is followed and the repayment starts after felling. The research institute particularly Forest College and Research Institute (TNAU) play a significant role for technological advancements through varietal development and also to advice site specific precision silvicultural technology to the growers. A pre and post-plantation scientific advice helps to develop human resources through on and off institute mode to farmers and plantation staff of the industries.

The industry mass multiply the potential genetic materials identified by the research institute in a decentralized manner and supply them at subsidized costs. The industry also facilitates felling and transport at their own costs, which resulted in strong linkage between industry and the farmers. The industry helps to repay the credit amount after felling of farm grown raw materials there by help the financial institutions for timely repayment, which resulted in strong institutional mechanism for sustainability of the contract dendro energy farming system in the state. These models were successfully

adopted in other industrial wood plantation programmes (Parthiban and Govinda Rao 2008; Parthiban et al, 2010 and Parthiban, 2016) and extend scope for its application in biofuel utility.

3



4

Fig 7. Quad-Partite Model Energy Farming Consortia Mode Energy Farming Methods

The following contract energy farming methods designed by Forest College and Research Institute of Tamil Nadu Agricultural University can be implemented in the farm lands in association with biofuel industries to generate solid and liquid fuels.

#### a. Farm Forestry Model

In this method, the biofuel industry can supply the quality planting materials of site specific variety identified by the research institute to the interested farmers on a subsidized rate. The farmers in turn develop his own plantation and obtain the needed technological support from the research institute. If needed, the farmers can get credit and insurance facility from the financial institutions and final felling and transportation by the biomass industry. An agreement can be made before the plantation establishment. In this method, the farmers grow only trees without any intercrop and mostly practiced in dry land condition.

#### b. Agroforestry Model

In this model the farmers can raise energy plantation as a major tree crop and grow suitable intercrops and this method can be practiced mostly in garden land conditions. The other conditions are similar to that of Farm Forestry model.

### c. Captive Model

In this method, the industry can develop their own plantation through land lease or benefit share model. The large land holders and the lands available with government and private sector which are unutilized for a longer period can be utilized. A minimum land size requirement of 10 ha. for 1 cluster unit is prescribed. Once the land is identified, the land holder can opt either land lease model or benefit share model.

#### 1. Land Lease Model

In this method, the land owner and the industry will have an agreement for lease amount and the lease period. Once the lease agreement is signed, the industry establishes their captive plantation and the period of lease is for one rotation and tenable further based on mutual consultations.

#### 2. Benefit Share Model

Under this method, the land owner agrees to share the benefits at the time of harvest. Accordingly, an agreement can be made wherein the industry establishes the plantation at its own cost and the benefit is shared at 70 (industry): 30 (land owner) for dry lands and 60 (industry): 40 (land owner) for garden lands. The benefit share is worked at the total yield of the produce.

#### 3. F. Summary and Conclusion

Energy is a critical and significant input for urbanization, industrialization and the associated socio-economic development. The energy strategy of India aims at providing energy to all through decentralized approach with a primary focus on providing clean and green source of energy. Accordingly energy generation has been attempted both for solid and liquid fuel generation using gasification, combustion and biofuel based processing technology. Wide range of biofuel industries have been established across the country with the available estimates of biomass availability from agriculture and allied sectors. However several of these industries are under threat due to non availability of adequate quantity and quality raw material resources. The existing agriculture based lignocellulosic biomass are deployed for wide range of value addition industries and hence their availability is dismally modest. Under such circumstances, the Tamil Nadu Agricultural University has developed a value chain model and demonstrated successfully in association with few industries. However for biofuel industry, this model needs to be demonstrated on a large scale in association with both liquid and solid based biofuel industries. The high yielding short rotation clones identified by TNAU have the great potential for biofuel utility and the current estimate indicated in this paper has extended greater scope for its adoption in biofuel sector.

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