Biomass Energy for Rural India

Carbon Mitigation Report

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ACRONYMS

AHF:	Agro-horti Forestry
AF:	Agro Forestry
ANR:	Assisted Natural Regeneration
BAU:	Business as Usual
BERI:	Biomass Energy for Rural India
BIRD-K:	BAIF Institute for Rural Development - Karnataka
BUG:	Biomass User Groups
CDM:	Clean Development Mechanism
CEA:	Central Electricity Authority
FF:	Farm Forestry
FSI:	Forest Survey of India
GEF:	Global Environment Facility
GHG:	Greenhouse gases
IC:	Internal combustion
ICEF:	India-Canada Environment Facility
IISc:	Indian Institute of Science’s
KPTCL:	Karnataka Power Transmission Corporation Limited
MNRE:	Ministry of New and Renewable Energy
PG:	Performance Guarantee

SHG:	Self-Help Groups
SOC:	Soil Organic Carbon
TBF:	Tree based farming
UNDP:	United Nations Development Programme
VFC:	Village Forest Committees (VFC)

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EXECUTIVE SUMMARY

BERI is one of the projects supported by UNDP and funded by Global Environment Facility (GEF) and co-financed by India-Canada Environment Facility (ICEF), Government of Karnataka and Government of India (Ministry of New and Renewable Energy (MNRE). The project was initiated in 2001.

The project broadly aims to "develop and implement a bio-energy technology package to reduce GHG emissions to promote a sustainable and participatory approach in meeting rural energy needs".

The main components of the project are:

1) Implement biomass gasifiers for electricity generation
2) Community biogas systems for cooking and meeting domestic loads.
3) Integrate efficient community irrigation processes

The project was envisaged to be implemented in 24 villages grouped into five clusters in the Tumkur district of Karnataka. The project is currently working in 31 villages and has progressed competently. The table below highlights key advancements completed under four indicators:

Table 1: BERI: Progress as of December 2010

Indicator	Achievements	Reach
Biomass	1,050kW cumulative installed capacity, through 11 gasifier/engine systems. 900 kW is 100% producer gas (three 100 kW systems, one 200 kW system, two 250 kW systems) One 100 kW dual fuel gasifier systems; and five 10 kW dual fuel gasifier systems.	2 clusters (Koratgere and Madhugiri) and approximately 15 villages. The power generated at the sites is at 415 V and it is stepped up to 11 kV before evacuating the supply to the grid.
Biogas	53 community biogas cum bio-fertilizer units	31 village settlements covering 171 households.
Afforestation	Plantations raised in about 3,000 hectares of forest and farm land. The plantations were set up mainly to fuel the biomass gasifiers. The Village Forest Committees (VFC) and forest department	Plantations raised across all 5 clusters, covering all 31 villages (Kabbigere, Gubbi, Tumkur, Koratagere,

	manage these plantations.	Madhugiri)
Irrigation	56 borewells dug for community irrigation Drip irrigation kits distributed	267 households across 5 clusters, covering 31 villages (Kabbigere, Gubbi, Tumkur, Koratgere, Madhugiri)

Source: BERI Project Implementation Report (2010)

The BERI project aims to contribute to carbon mitigation through the following activities:

- Partial replacement of traditional fossil fuels through the application of renewable bio-energy in the form of biomass gasifiers for electricity and biogas for cooking
- Use of carbon sinks through the afforestation and reforestation efforts, saving carbon
- Use of efficient cook stoves thereby reducing the harmful GHG's in the atmosphere.

The scope of the study covers:

- The BERI project area: Five taluks under the Tumkur district of Karnataka, which include, Tumkur, Koratgere, Gubbi, Madhugiri and Sira
- Estimated carbon emissions and reduction scenarios, where 'carbon' refers to just CO_2

The methods used for the three components are as follows:

1. Assessing carbon savings from biomass power plants

   The total fossil fuel power substituted through the deployment of biomass power plants can be estimated. This helps assess the net carbon mitigated since inception of the project. Carbon savings achieved as a result of the induction of biomass power required an impact assessment framework. The impact assessment will use a Business as Usual (BAU) scenario against a BERI project scenario.

2. Assessing carbon savings from afforestation

   Based on an extensive field assessment of forest and farmland cultivated as part of the BERI project, the carbon sequestration and the carbon stock and flow were estimated. Above ground biomass, below ground biomass and soil carbon analysis was conducted as part of the assessment.

3. Assessing carbon savings from community biogas units

   Similar to stage 1, the total fuel wood usage substituted through the installation of community biogas units is assessed. A BAU scenario was developed to establish past trends in fuel wood use per family; following which the carbon stock can be established. Once this is established, a BERI project scenario will be ascertained thereby signaling the net carbon reductions achieved by the BERI project through the introduction of biogas for cooking.

The outcome of the above three stages was to provide a cumulative measurement of additionality or incrementality associated with changes in carbon stock, in particular carbon emission reduction due to project activities in relation to the three main activities associated with the project. The carbon emissions reduction is analysed from power generation, running of biogas plants, and CO_2 sequestration from cultivation of energy plantations.

Assessing carbon savings from biomass power plants

Two scenarios were used to assess the carbon mitigation potential arising from the institution and running of the biomass power plants as part of the BERI project. The results indicate that scenario 1, would result in total carbon savings of 198.44 tCO_2 from 2001-2010, and annual savings of 22.04 tCO_2. In an optimistic scenario two, total carbon savings of around 374.74 tCO_2 from 2001-2010 equating to annual savings of around 41.6 tCO_2 were estimated.

Assessing carbon savings from afforestation

The BERI project has instituted afforestation of common lands and forest lands in addition to promoting tree based farming. These activities generate significant carbon pools that contribute to mitigating GHG emissions from the BERI project. There are four carbon pools in such activities – aboveground biomass, belowground biomass, dead organic matter that includes dead wood and litter, and soil organic carbon. Furthermore, a certain amount of wood is extracted for functioning of the biomass gasifiers and this amount needs to be subtracted the overall carbon pools that determine the sequestration benefits of the project.

Overall, 2933.44 ha of forest and farm land have been cultivated since inception of the BERI project. Field visits and subsequent calculations have indicated the total carbon pool increment (compared to the baseline) in the project area, to be 239222 tCO_2 (including for extraction).

Assessing carbon savings from community biogas units

The total fuel wood use reduced by the installation and use of the BERI project is calculated as 1.5 tonnes/household/year. Estimating this for the total 86 households benefiting from biogas, gives a total fuel wood conservation of 129 tonnes/year. Discounting for unsustainable extraction amounts to 86.5 tonnes/year. Overall, the assessment found that the total carbon emissions saved from the installation and use of biogas plants since inception can therefore be calculated to be 1428.5 tCO_2.

Overall, combining all estimates, the overall carbon savings from the BERI project as of January 2011 is 240849.2 tCO_2. The annual target achieved by the BERI project as of 2010 is 26,761 tCO_2 annually. The contribution of the afforestation and reforestation efforts contributes the maximum amount to the carbon mitigation. It is however expected the biomass gasifiers and biogas units will be functioning at full technical potential by the time the project draws to a close in 2012. This will sufficiently increase the carbon emissions saved from biomass power and biogas in the project area.

1. INTRODUCTION

1.1 Context and purpose

A key output of the BERI project is to reduce CO_2 emissions through the promotion of bio-energy as a viable and sustainable option to meet rural energy service needs in India.

This study undertakes an analysis of carbon savings achieved by the BERI project and its related activities, as of July 2010. Additionally carbon savings to be achieved by the project activities in the future have also been assessed. The five main objectives of the study are to:

- Review of the project objectives and achievements to highlight the means to reduce carbon savings
- Assessment of CO_2 mitigation on an annual basis from power generation, running of biogas plants, use of improved cook stoves
- Assessment of CO_2 sequestered from cultivation of energy plantations for the purpose of the project
- Conduct a high-level assessment of the range of potential carbon savings achievable by the BERI project by 2020, through the continued successful implementation of its key objectives
- Identify further activities that could enable the project to contribute its fair share to regional carbon reduction targets, and provide an evidence base to help prioritise future regional policies and actions.

1.2 Background

BERI – The project

BERI is one of the projects supported by UNDP for achieving the millennium development goal of ensuring environment sustainability and thereby reducing poverty. The project is funded by Global Environment Facility (GEF) and co-financed by India-Canada Environment Facility (ICEF), Government of Karnataka and Government of India (Ministry of New and Renewable Energy (MNRE). The project was initiated in 2001.

The project broadly aims to “develop and implement a bio-energy technology package to reduce GHG emissions to promote a sustainable and participatory approach in meeting rural energy needs”. The project was conceptualized to be multi-faceted in that apart from meeting rural energy needs and reducing CO_2 emissions, it would galvanize self-reliance, local employment, gender and health related issues in addition to land reclamation. The focus was to meet the energy needs of these services of the rural population viz. heat energy for cooking and electricity for lighting and shaft power, through a bio-energy package. The specific goals of the project are (UNDP, 2001):

- Demonstrate technical feasibility and financial viability of bio-energy technologies in a large scale
- Build capacity and develop mechanisms to implement, manage and monitor such projects
- Develop strategies to overcome technical, financial, institutional and market barriers for bio-energy packages and
- Disseminate bio-energy technologies across India.

The main components of the project are:

1. Implement biomass gasifiers for electricity generation
2. Community biogas systems for cooking and meeting domestic loads.
3. Integrate efficient community irrigation processes

The BERI project area is shown in Figure 1.

Study Area

The project area is located within five clusters in the Tumkur district of Karnataka in Southern India (see figure 1.1). Karnataka's population accounts for 448 lakhs, 5.3% of the total Indian population. Tumkur district covers 5.5% of Karnataka and accounts for 5% of the state population. A considerable 80.38% of the population in Tumkur district is rural. Furthermore, approximately 80% of the population in the Tumkur district relies on agriculture and related activities such as cultivation. Of those, only 9% come from the urban areas of Tumkur (Census 2001). It is a characteristic agricultural zone in the semi-arid belt of Karnataka

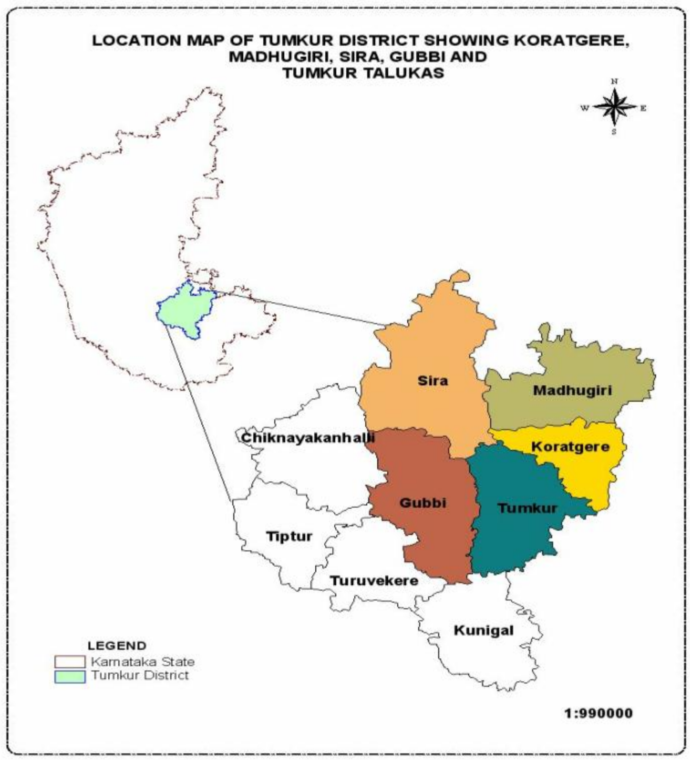
Salient features of the district that justify its position for the project were identified as follows (Hiremath et al., 2010):

- Only 60% of households in rural Tumkur have access to electricity
- It has 410,342.00ha under wasteland, which accounts to 34% of the total area of the district indicating a large potential for biomass feedstock production for energy
- Only 4.2% of the total area of the district is classified as forests, highlighting the need to enhance forest cover through afforestation programmes

- The number of pump sets per hectare of irrigation land is very high indicating the need for reliable power supply

- A large area of Tumkur is covered by mulberry and coconut plantations, with high potential for biomass feedstock supply for energy

Figure 1.1: BERI project area



Source: BERI, 2007

Key Achievements

A review and analysis of existing data highlights some of the key benefits accrued from the progress made, as of June 2010:

- GHG mitigation: An initial high level assessment suggests, GHG savings from from forestry/afforestation, biomass power generation, biogas units is likely to be significant. This is further examined in this study. .

- Employment: The energy plantations have led to more than 30 people directly employed and many more employed indirectly. Importantly, about 100 women are employed indirectly in maintenance and harvesting of energy plantations. In the past year alone (2009-2010), approximately 600 tonnes of biomass was harvested with local farmers earning approximately Rs. 1,200 per tonne of biomass harvested. 10 men and 2 women are also currently trained and employed in the daily operation and maintenance of the functioning biomass gasifier plant in Kabbigere.

- Gender, health: Work involving community mobilization in the five village clusters, including capacity building, increasing involvement of women in planning and management of nursery & plantation is central to the project. This has taken the form of Biomass User Groups (BUG) and Self-Help Groups (SHG) among others. Energy use patterns have serious implications both on the environment as a whole as well as on the users. Fuel wood requirements have contributed to the degradation of forests leading to villagers, especially women traveling longer distances and spending more time in collecting fuel wood; switching to inferior fuels. Women in these villages spend a large portion of the day in the kitchen and the health implications of working in close quarters with burning firewood cannot be neglected. The project has provided biogas plants as clean fuel option to help negate this.

- Capacity building: Overall capacity building by the project has led to improvements within the societies benefitting from the project. For instance, Self Help Groups (SHGs) have been set up by the women with the help of local NGOs like BAIF Institute for Rural Development - Karnataka (BIRD-K) among others.

Key Barriers

One of the main justifications provided whilst approving this project was that despite their technical feasibility and multiple benefits, bio-energy technologies have not spread in India, apart from a few isolated demonstration projects. In instituting and implementing the BERI project, a number of these key barriers have come to the fore. This will further help explore the reasons for the slow growth in bio-energy in rural India. The barriers faced include the following:

- Technical barriers: Since the beginning, BERI gasifiers have faced technical glitches due to which the Performance Guarantee (PG) tests have not been completed. The Performance Guarantee test requires the gasifier/engine set to run continuously for 300 hours at 95% rated capacity and specific fuel consumption of 1.25 kg/kWh. Currently, one, 100 kW gasifier is undergoing the test and the repairs of the other systems will be taken up subsequently.

- Information barriers: Bioenergy, despite its historical role in the Indian energy scene, is yet to fully be acknowledged as a reliable energy source, especially in rural areas. There is still a general lack of understanding on the benefits of bioenergy.

- Market barriers: All electricity produced is being sent to the grid. Subsequently this brings with it problems relating to grid unavailability leading to poor performance. Grid connectivity is limited to five to six hours a day and without grid power the gasifiers cannot be started. The generators are automatically disconnected from the grid during a grid failure or during excessive voltage or frequency fluctuations leading to poor returns.

- Financial barriers: The project is yet to demonstrate its economic and financial viability and is currently running losses per unit of electricity generated. Additionally, a large part of the co-financing initially put forth for this project up to the value of $1.6 million is being discontinued.

Most recently the 1 MW gasification system at Kabbigere village completed a continuous 1000 hour run without interruptions and at 80-85% of rated load. This has paved the way for the removal of the technical impediments and acts as benchmark for biomass gasification systems in India. No other grid-connected gasification system has demonstrated an uninterrupted run for this long and with such high rated load. It is expected that all other installed gasifiers can now be brought to this operational loads in due course. This has provided BERI with a renewed vigor and the management is looking to address a majority of the barriers above.

1.3 BERI and Climate Change Mitigation

Climate change mitigation involves reductions in the concentrations of greenhouse gases (GHGs) either by reducing the sources or increasing their sinks. Climate change mitigation can be differentiated from climate change adaptation in that, it is for preventing future global warming as opposed to reversing or adapting to the existing effects of global warming. Mitigating climate change has seen increased efforts in developing new technologies and mechanisms whilst carefully managing the existing ones, so as to minimize impacts on the environment. Nicholas Stern, author of the UK government's seminal Stern Review on the Economics of Climate Change states that there are three elements to carbon mitigation; carbon pricing, technology and behavioral change.

The most popular means of mitigating climate change globally are through, the development and use of cleaner energy sources (such as renewable energy), the reduction of energy waste, energy conservation, changing consumption patterns and the use of carbon sinks, carbon credits and carbon taxes. All these will contribute to the reduction in GHG emissions.

The BERI project aims to contribute to carbon mitigation through the following activities:

- Partial replacement of traditional fossil fuels through the application of renewable bio-energy in the form of biomass gasifiers for electricity and biogas for cooking. The biomass fuel source is from energy plantations dedicated for the same.

- Use of carbon sinks through the afforestation and reforestation efforts, saving carbon
- Use of efficient cook stoves thereby reducing the harmful GHG's in the atmosphere.

The following sections will highlight in detail the total carbon mitigated through each of the above activities since the inception of the BERI project.

1.4 Methodology Overview

Scope of the study

The scope of the study covers:

- The BERI project area: Five taluks under the Tumkur district of Karnataka, which include, Tumkur, Koratgere, Gubbi, Madhugiri and Sira
- Estimated carbon emissions and reduction scenarios, where 'carbon' refers to just CO_2

Estimated carbon emissions and reduction scenarios are presented by the three key BERI project activities mentioned in the project document, which are:

- Biomass power generation
- Cultivation of energy plantations
- Biogas for cooking needs

Emission savings cover those that can be achieved through the reduction of direct emissions within the project area as well as indirect emissions from the region's (Tumkur district) electricity use. Other indirect carbon savings, such as those associated with the reduction of emissions from the provision of improved cook-stoves[1] and drip irrigation kits[2] are not taken into account due to limited usage and incomplete data

[1] Improved stoves are more efficient, meaning that the stove's users spend less time gathering wood or other fuels, prevention of lung diseases prevalent in smoke-filled homes, while reducing deforestation and air pollution. The main goal of most improved cooking stoves is to reduce the pressure placed on local forests by reducing the amount of wood the stoves consume, thereby sequestering greater amounts of carbon.

[2] Drip irrigation, saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. Replacing an existing irrigation system with a drip irrigation set for a typical cultivated area in the region is will save energy.

availability (although this is clearly an area of interest that could attract further investigation).

Key Stages

The methods used for the three components are as follows:

1. Assessing carbon savings from biomass power plants

   The total fossil fuel power substituted through the deployment of biomass power plants can be estimated. This helps assess the net carbon mitigated since inception of the project. Carbon savings achieved as a result of the induction of biomass power required an impact assessment framework. The impact assessment will use a Business as Usual (BAU) scenario against a BERI project scenario.

   - BAU Scenario: This scenario in this study refers to the situation on field before the institution of the BERI project. As the thrust of the project is to provide services via renewable energy, defining the baseline is somewhat complex. Three services are highlighted in the project document - electric lighting, irrigation water pumping and gas for cooking. Two potential BAU scenarios are explored keeping in mind the various possibilities.

   - BERI project scenario: The BERI project scenario refers to the situation after the institution of the BERI project. In the case of BERI, this scenario will lay out the progress made by the project in terms of development and deployment of biomass power plants in the project area.

   The net carbon benefit was calculated using the results of the above assessment framework.

2. Assessing carbon savings from afforestation

   Based on an extensive field assessment of forest and farmland cultivated as part of the BERI project, the carbon sequestration and the carbon stock and flow were estimated. A total of 123 plots were laid, covering 28.95 ha of afforested land. Above ground biomass, below ground biomass and soil carbon analysis in the laboratory was conducted as part of the assessment.

3. Assessing carbon savings from community biogas units

   Similar to stage 1, the total fuel wood usage substituted through the installation of community biogas units is assessed. A BAU scenario was developed to establish past trends in fuel wood use per family; following which the carbon stock can be established. Once this is established, a BERI project scenario will be ascertained thereby signaling the net carbon reductions achieved by the BERI project through the introduction of biogas for cooking.

The outcome of the above three stages was to provide a cumulative measurement of additionality or incrementality associated with changes in carbon stock, in particular carbon emission reduction due to project activities in relation to the three main activities associated with the project. The carbon emissions reduction is analysed from power generation, running of biogas plants, and CO_2 sequestration from cultivation of energy plantations.

Key activities

The overall assessment was a combination of:

- Compilation of existing data sources and historical data;
- Extensive field studies and a survey of land used for forestry, households, industries, the agriculture sector; and
- Participatory rural appraisal based on local community knowledge.

Caveats

The estimates developed in this study are subject to a double uncertainty, namely an uncertainty of human error since extensive field analysis was conducted, and an uncertainty about the data used to estimate the carbon savings. Any potential caveats affecting the robustness of the results are addressed individually in each section.

2. CARBON SAVINGS FROM BIOMASS POWER PLANTS

This chapter presents our analysis of the carbon savings achieved from the introduction of biomass based power plants, and the key findings of this assessment.

2.1 Introduction

Biomass is renewable organic matter derived from plants or from human, animal and municipal or industrial waste. It is an abundant and carbon-neutral source of energy, which has a potential to meet 15 to 50% of the world energy need by 2050. In India, 32% of the primary energy need is met from biomass and 70% of the rural population uses biomass for energy needs. The energy derived from biomass is called bio-energy and the bio-energy technologies convert raw biomass into a higher-grade energy such as electricity, gas or bio-fuel. The three main technologies for utilizing biomass are bagasse cogeneration, biomass combustion and biomass gasification for thermal and electrical applications. Biomass gasification is a thermo-chemical conversion of biomass into a combustible gas mixture called producer gas. The producer gas is then combusted in an internal combustion (IC) engine coupled with a generator to produce electricity. This is a more cleaner and efficient way to use biomass. The biomass used can be woody biomass or non-woody biomass such as rice husk, coconut shells etc. The producer gas can be used in a dual-fuel engine or a 100% producer gas engine. The cost of power generation through biomass gasification route could vary and is reliant on three key aspects (i) biomass cost, (ii) operational costs including maintenance, labour etc. and (iii) capital recovery. Biomass gasification based power generation is often found to be financially unattractive for replacing grid electricity and most of the biomass gasification power plants in India are dependent of the additional revenue from carbon credits, irrigation water system, etc.

Burning plant biomass as a fuel source does not result in net carbon emissions since the bioenergy will only release the amount of carbon they have absorbed during growth (providing production and harvesting is sustainable). If this energy is used instead of fossil fuels, carbon emissions from the displaced fossil fuels are avoided as well as other associated pollutants such as sulphur[3].

Thus biomass power for power generation offers one of the most promising future carbon mitigation options. Traditionally used coal combustion for electricity generation is associated with two negative externalities - namely CO_2 and SO_2 emissions. Typical coal used in Indian power plants emits 3.2 tons of carbon per tera joule (tC/TJ) and 0.1 ton of sulfur dioxide per TJ.

[3] The avoided emissions from the substitution of fossil fuels are only half the story. A large the benefit of carbon mitigation lies in the energy plantations raised in the forest and farm lands. This will be explored in detail in the next section.

If biomass is produced more efficiently and used with modern conversion technologies, it can supply a considerable range and diversity of fuels at small and large scales. Much more useful energy could be extracted from biomass than at present and this could allow a break in the "energy ladder" and some relief to the energy problem. Since bioenergy can be used at small and large scales in a centralised and decentralised manner this can bring substantial benefits to rural (and even urban) areas which don't usually have access to modern energy carriers.

In calculating the environmental impact of biomass gasification, biomass is assumed to replace coal-based power, as coal is a dominant source of energy for power generation[4]. CO_2 from coal combustion is the dominant GHG contributing to climate change in India. The potential CO_2 emissions avoided by shifting to renewables have been globally recognized. A study on potential of biomass power for decentralised applications alone has shown that nearly 40 million tC emission could be avoided in total by shifting kW scale (20 to 200 kW) biomass gasifiers for rural electrification in India (Ravindranath and Hall, 1995).

The BERI project was formulated with a similar aim of carbon abatement through the substitution of coal based power with renewable power. The total abatement achieved is assessed and key findings highlighted in the following sections.

2.2 Methodology - Assessment Framework

The assessment framework presents two scenarios, the business-as-usual (BAU) scenario and the project scenario. The findings will highlight the key carbon mitigation potential from the implementation of the biomass gasifiers as opposed to the BAU scenario. The following sub-sections highlight the key steps followed (See Box 1):

[4] Indian villages with no or erratic supply of power, use diesel gensets – a fossil fuel with higher CO2 emission factor

BOX 2.1

Key Steps:

1. Establish the BAU scenarios: Determine through a study of baseline data, where available
2. Establish the BERI project scenario: Determine the total power generated by the biomass power plants set up by the BERI project
3. Assessment of Net carbon savings: Using information from government of India and Government of Karnataka, assess to the most accurate level possible, the total percent of electricity likely to come from fossil fuel sources i.e coal. This is the business-as-usual scenario
4. Estimate the total fossil fuel power substituted by the induction of biomass power plants in the BERI project
5. Determine the CO_2 emissions saved per unit of power generated using IPCC estimate for the total fossil fuel substituted

Step 1: Baseline/Business as Usual Scenario

This section establishes a BAU scenario in terms of power generated and supplied. Baseline data and existing regional and national data were used to determine the potential power generation credentials of the BERI project. The existing and future impacts arising from the project were then assessed relative to the impact on the environment and local community.

In assessing the baseline for the eventual mitigation potential of the biomass gasifiers installed and run as part of the BERI project, a comprehensive analysis was conducted. A detailed review of background information and existing data sources on power generation and consumption under the project areas was conducted. The sources of energy supply reviewed were as follows:

- Grid electricity: a review of the total electricity consumption in the project area. Data from the Karnataka Power Transmission Corporation Limited (KPTCL) was collated
- Diesel for pumping: a survey of sample diesel pump owners
- Kerosene used for cooking and lighting: a household survey was conducted
- Fuel wood used for cooking: a household survey was conducted

A key caveat is the absence of detailed power generation and consumption data for the project area. The baseline and BAU scenario is in this analysis recreated based on available information. The existing literature reviewed suggests a number of potential options for reliable energy services that would have been used in the project area 10 years ago, such as extending the grid or using diesel gen-sets for meeting electricity needs and supply LPG for cooking. When scoping through potential options a number of limitations come to the fore. These are addressed in Box 2 below.

BOX 2.2

CAVEATS

The project report as of March 2001, identifies, if business-as-usual energy consumption patterns are not viewed as exogenous and ‘‘given’’, but as alterable through interventions, then the question arises regarding the nature of the interventions to influence these patterns. Obviously, the interventions must depend upon the determinants of energy consumption.

Therefore under the baseline, there are various options for considering reliable energy services, such as extending the grid or using diesel gen-sets for meeting electricity needs and supply LPG for cooking. Since the power generated from the biomass power plants was to be directly exported to the grid, assessing the mitigation implications of diesel, kerosene and firewood is not necessary. This is mainly because, diesel pump-sets, kerosene for lighting and cooking and firewood for cooking are unlikely to be substituted by biomass power. The reasoning behind this is that if the biomass power supply was decentralized and large enough to overcome demand, the project area would in all likelihood achieve a complete shift from these more polluting sources of power. However, whilst biomass power is a renewable power, grid-connected biomass power supply is still subject to the aforementioned problems associated with connecting to the national grid, such as consistent power shortages among others.

Therefore it has been assumed that diesel, kerosene and firewood are still being used by the villages under the project area and baseline data for the above is not considered.

BESCOM does not provide district and taluk level data on electricity consumption to assess their potential carbon reduction impact. Therefore a significant amount of information had to be collected and analysed as part of this study, through desktop research and discussions with stakeholders in order to identify data whose impact on GHG emissions could be quantified with a minimum level of accuracy. However, the level of uncertainty associated with these estimates can be classified as low.

Keeping in mind the above limitations in baseline data (see Box 1), the best way forward was considered to be by assessing the potential mitigation benefits of the shift to grid-connected biomass based power supply through the amount of fossil fuel power supply substituted. A key variable in this method is the percentage of power likely to come from coal-based sources in the BAU scenario. Therefore using baseline data on the percentage of coal-based electricity for Karnataka, the CO_2 emissions saved per MWh of biomass power generated is assessed.

The Ministry of Power is the apex body responsible for the development of electrical energy in India. In June 2010, the installed power generation capacity of India stood at 162,366 MW, while the per capita energy consumption stood at 612 kWh. About 70%

of the electricity consumed in India is generated by thermal power plants, 21% by hydro-electric power plants and 4% by nuclear power plants. approximately 53.3% of India's commercial energy demand is met through the country's vast coal reserves. See Table 2.1 for more details:

Table 2.1: Installed Power Generation in India by Source, 2010

Source of Fuel	MW	%
Coal	89,778.38	53.3
Gas	17,384.85	10.5
Oil	1,199.75	0.9
Total Thermal	108362.98	64.6
Hydro Renewable	37,367.40	24.7
Nuclear	4,560.00	2.9
RES**(MNRE)	16,786.98	7.7
Total	**1,67,077.36**	

Source: www.powermin.nic.in (2010)

Two baseline scenarios have been developed. In scenario 1, since a majority of electricity generated comes from coal, it is assumed that coal is the fossil fuel most likely to be substituted through the introduction of biomass energy. Therefore, 53.3% of fossil fuel based electricity is assumed to be substituted by renewable energy in the BERI project. In scenario 2, it is assumed that all marginal capacity additions are likely to come from coal. Therefore, 100% of the fossil-fuel based electricity is assumed to be substituted by renewable energy from the BERI project.

Step 2: BERI Project Scenario

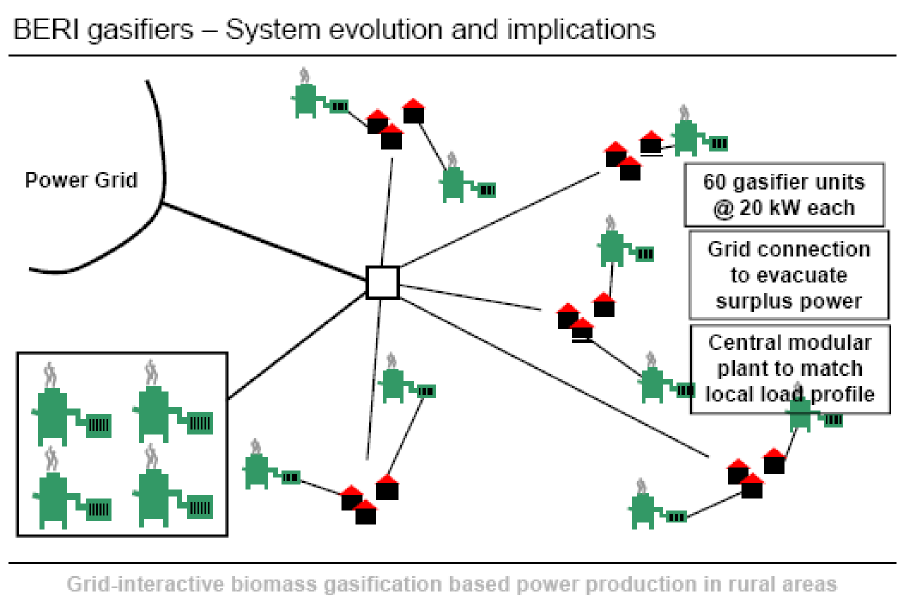
Whilst it was initially decided to operate the biomass power plants in a decentralized way, grid connected power was considered a more feasible option. All the villages under the project area were already connected to the grid. Power supply was however inconsistent and the cost of electricity in decentralized mode was found to be higher than the subsidised electricity tariff charged currently. Critically, the installed capacity planned as part of BERI project constitutes to less than 25% of the local consumption. The estimated local load in all the five clusters is shown in Table 2.2.

Table 2.2: Total electricity consumption in BERI project area under BAU (2007)

Cluster	Total electricity consumption (MW)
Sira	40.32
Madhugiri	450.84
Tumkur	728.15
Koratagere	1715.62
Gubbi	1137
Total	**4071.93**

Source: BERI, 2007

Figure 2.1: Evolution of BERI gasifiers



Thus it was decided that the villages would be grouped into clusters based on biomass availability and local demand; and these clusters could be disconnected from the grid. The electricity generated would then be exported to the grid. Of the five clusters, the biomass gasifier/engine sets have been installed in two clusters till date. Both cluster 1 (Koratagere taluk, Kabbigere site) and cluster 2 (Madhugiri taluk, Boregunte and

Sheebanayanapalya sites) have an installed capacity of 500 kW each[5]. The breakdown is as follows:

In Cluster 1 (500 kW):

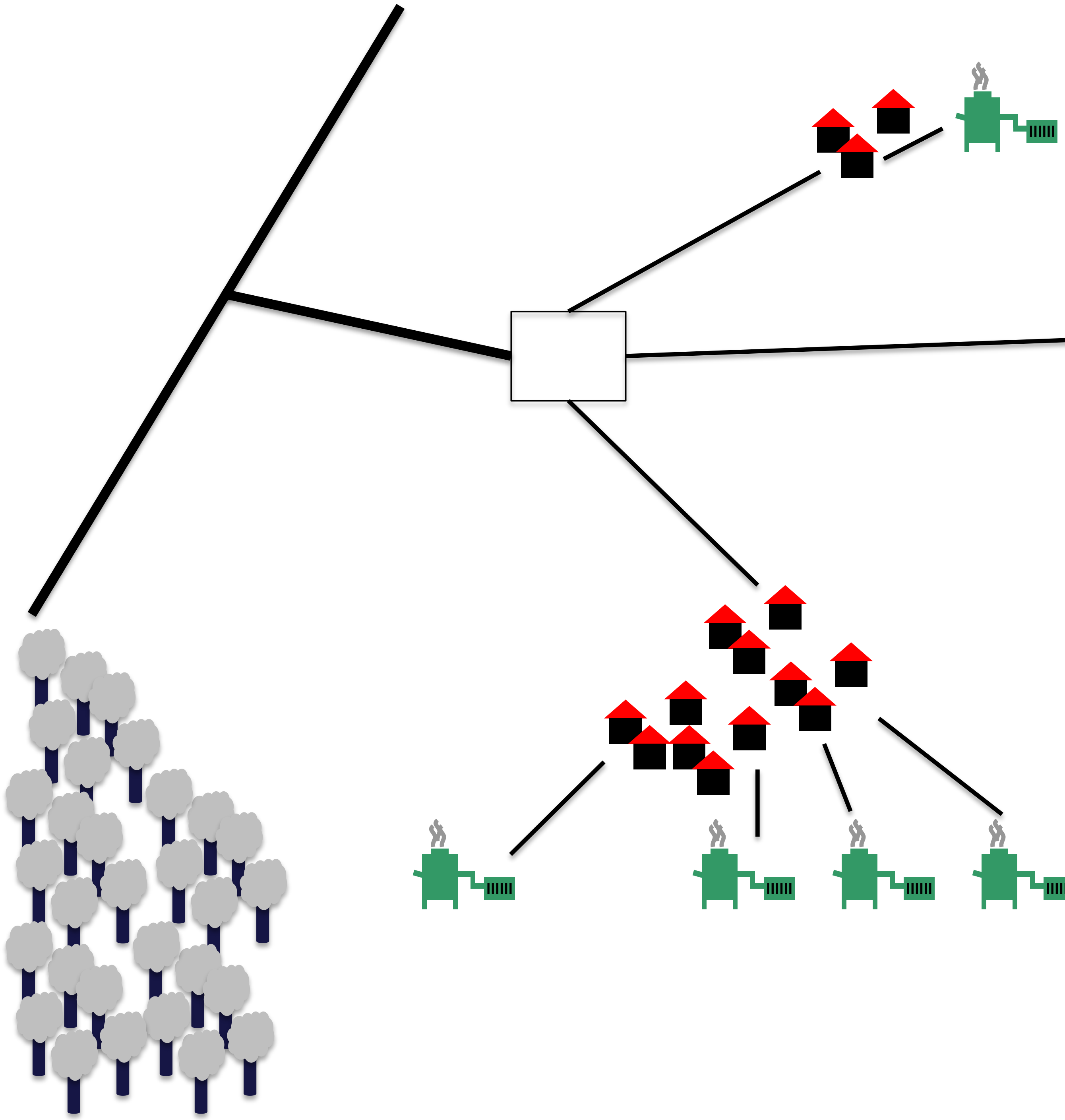
- 1 x 100 kW dual-fuel gasifier
- 2 x 100 kW producer gas system
- 1 x 200 kW producer gas system

In Cluster 2 (500 kW):

- 2 x 250 kW producer gas system

Figure 2.2: Layout of BERI gasifiers

[5] There are a further five 10 kW dual fuel gasifiers installed solely for the purposes of demonstration.



The power generated at the site is at 415 V and it is stepped up to 11 kV before evacuating the supply to the grid.

The biomass gasifiers are fuelled using wood from fast growing energy and farmland plantations set up as part of the project. Almost 3,000 ha of land have been used for energy plantations as part of this initiative. Village Forest Committees (VFC) and forest department manages these plantations. The layout of the gasifiers in clusters one and two are indicated in figure 2.2 below:

The gasifiers installed in BERI project utilized the Indian Institute of Science's (IISc) technology on biomass gasification. The manufacturers involved in BERI were Energreen and Netpro. Energreen installed two engine/generator sets in cluster 1 (Koratgere) and Netpro installed all other sets. The biomass gasifiers were installed in cluster 1 on 2005 and it started operation in 2007. The cluster 2 systems are yet to start operation.

The BERI gasifiers have faced contractual and technical glitches since installation. The issues are currently being addressed and Performance Guarantee (PG) tests are being conducted on the gasifiers. The Performance Guarantee test requires the gasifier/engine set to run continuously for 300 hours at 95% rated capacity and specific fuel consumption of 1.25 kg/kWh. Currently, one of the 100 kW gasifier is undergoing the test and the repairs of the other systems will be taken up subsequently. IISc's technicians are available on-site for resolving the issues and original manufactures are no longer involved in BERI. some of the performance issues has been attributed to bad construction, necessity of on-field system improvements, and poor quality of biomass. Almost 70 – 80% of the problems occur in gas cleaning and cooling systems.

Apart from the technical problems, grid unavailability is another reason for low plant performance. The grid connectivity is limited to five to six hours a day and without grid power the gasifiers cannot be started. The generators are automatically disconnected from the grid during a grid failure or during excessive voltage or frequency fluctuations. The remaining barriers for successful operation are biomass procurement issues, lack of trained personal and inconsistent gas quality.

The following table presents the total amount of power generated by the gasifiers in cluster 1::

<u>Total Capacity:- 500 KW</u>

i) 200 KW (gas engine) - DG-1

ii)100 KW (gas engine) - DG-2

iii) 100 KW (gas engine) - DG-3

iv)100 KW (dual mode) - DG-4 (Kept Idle)

Table 2.3: Total Power Generated

Year	Total number of days working	Total generation (MWh)
2007	123	76
2008	163	138
2009	73	53
2010	207	190
Total	**566**	**457**

Source: BERI 2011

Most recently the 1 MW gasification system at Kabbigere village completed a continuous 1,000 hour run without interruptions and with efficiency levels of 80-85%. This has paved the way for the removal of the technical impediments and acts as benchmark for biomass gasification systems in India. No other grid-connected gasification system has demonstrated an uninterrupted run for this long and with such high efficiency levels. It is expected that all other installed gasifiers can now be brought to this operational efficiency in due course.

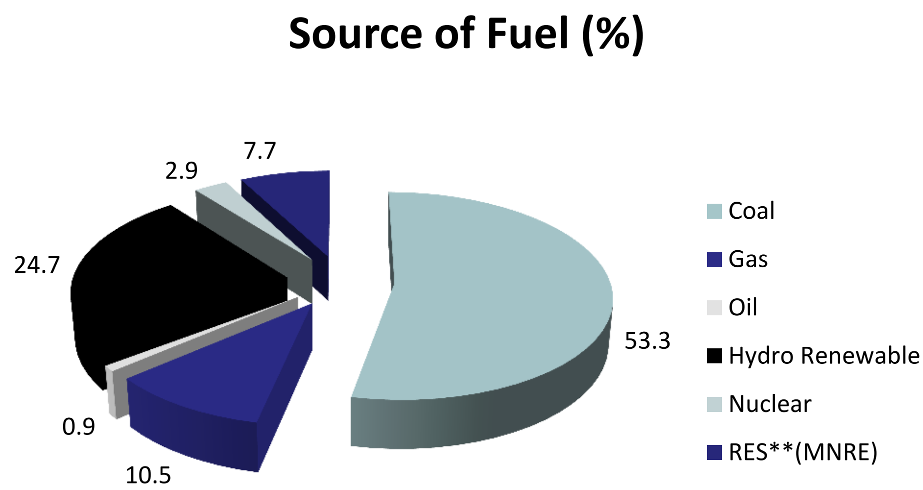
The cumulative power generated by the total 500 kW functioning biomass gasification systems is 457 MWh as of January 2011[6].

Step 3: Net Fossil Fuel Substituted

As indicated in figure 2.3, the total power generated, approximately 70% of the electricity consumed in India is generated by thermal power plants, 53.3% of which are coal based.

[6] Annex 1 shows the detailed power generation figures for the gasifiers

Figure 2.3: Sources of fuel, India (2010)



Source: Ministry of Power, Govt. of India (2010)

Coal-based power is the dominant source of energy in India. Emissions from coal-fired plants have substantial impacts on both air quality and climate change. Large amounts of CO_2 are emitted, which leads to global warming and associated climate changes. In the BAU case, two scenarios based on coal have been applied.

Scenario 1:

Since a majority of electricity generated in India comes from coal, it is assumed that coal is the fossil fuel most likely to be substituted through the introduction of biomass energy. Therefore, 53.3% of fossil fuel based electricity is assumed to be substituted by renewable energy in the BERI project[7]. Thus, approximately 53.3% of the 457 MWh of power now produced from the biomass power plants, would instead have come from coal-based sources. This accounts to 242 MWh of the electricity generated. The remaining 215 MWh is assumed to come from renewable based energy sources and will not have an impact on this assessment[8].

[7] This method is commonly used by academics to assess the baseline scenario. See Ravindranath and Ostwald (2008), Carbon Inventory Methods - Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production projects, Springer

[8] The power produced by the gasifiers is mapped to the energy mix that supplies power at the national level. Thus 53.3% is assumed to come from coal. The remainder of the 46.7% is not broke up along similar lines since oil and

Overall this assessment concludes that in the absence of the project, 242 MWh of electricity would still be derived from fossil-fuel based sources. The total carbon mitigated through the introduction of biomass-based power plants will be estimated below.

Scenario 2:

It is assumed that all incremental capacity additions are likely to come from coal. 100% of the fossil-fuel based electricity is assumed to be substituted by renewable energy from the BERI project. Therefore, 457 MWh of power now produced from the biomass power plants, would instead have come from coal-based sources. The total carbon mitigated through the introduction of biomass-based power plants in this scenario will be estimated below.

Step 4: Total Carbon Savings Achieved

The total carbon savings achieved can be calculated using the net fossil fuel substituted and the CO_2 emissions saved per unit of fossil fuel substituted. See equation (1) below.

*CO_2 emissions avoided (tCO_2) = Power Generation substituted (MWh) * Emissions Factor (tCO_2/MWh)*

The total coal-based generation substituted was estimated in the section above and is 242 MWh.

The emissions factor i.e. the CO_2 emissions per unit of electricity requires sophisticated estimation techniques due to a number of variants. CO_2 emissions per unit of electricity generated depend on the characteristics of the fuel and power plant. Characteristics of the fuel include the energy and carbon content of the fuel, and that of the power plant include its heat rate, i.e., the amount of energy required to produce one unit of electricity, and the PLF. Emissions produced are thus calculated using the following equation (2).

*CO_2 emissions per unit of electricity generated (kg C/kWh) = (Carbon content of the fuel (kg C / kg of fuel) / Heat value of the fuel (GJ / kg of fuel)) * heat rate of the power plant (GJ / kWh)*

The IPCC provides a simple solution by releasing emission coefficients that can be used as default values in studies such as these. The IPCC calculates emission factors assuming a linear relation between the intensity of the activity and the emission resulting from this activity.

gas based sources will have a miniscule impact on GHG emissions. Further to this nuclear and renewable sources are likely to have a zero GHG emissions.

Table 2.4: IPCC Emission Coefficients

Type of coal	India Specific Emission factors
	tCO_2/TJ
Cooking Coal	25.53
Non-cooking coal	26.13
Lignite	28.95

Source: IPCC (2006)

In India, the Central Electricity Authority (CEA) has taken the initiative to publish the CO2 baseline database for the Indian Power Sector to assist Clean Development Mechanism (CDM) project developers for speedy approval of their CDM projects. The CEA has come out with different CO2 emission co-efficient for different grids. The Indian electricity system is divided into two grids, the Integrated Northern, Eastern, Western, and North-Eastern regional grids (NEWNE) and the Southern Grid. The Weighted average emission factor, provided by the CEA for the Southern Grid, is 0.82[9].

The figure used in this analysis is based on the CEA emission coefficients. Scenario 1:

Therefore substituting the values for the equation (1) in Scenario 1 mentioned above,

CO_2 emissions avoided = 242 MWh * 0.82 tCO_2/MWh

= 198.44 tCO_2

Therefore, the overall carbon mitigated by the BERI project through the development and use of biomass gasifiers is 198.44 tCO_2.

Scenario 2:

Substituting the values for the equation (1) in Scenario 2 mentioned above,

CO_2 emissions avoided = 457 MWh * 0.82 tCO_2/MWh

= 374.74 tCO_2

Therefore, the overall carbon mitigated by the BERI project through the development and use of biomass gasifiers is 374.74 tCO_2.

[9] CEA (2009), CO_2 Baseline Database for the Indian Power Sector, Ministry of Power, Government of India

2.3 Key Findings

Two scenarios were used to assess the carbon mitigation potential arising from the institution and running of the biomass power plants as part of the BERI project. The results indicate that scenario 1, would result in total carbon savings of 198.44 tCO_2 from 2001-2010, and annual savings of 22.04 tCO_2. In an optimistic scenario two, total carbon savings of around 374.74 tCO_2 from 2001-2010 equating to annual savings of around 41.6 tCO_2 were estimated.

The project document, prepared in 2001, had projected the carbon mitigation potential of energy substituted from the use of biomass power plants to be approximately 3,802 tCO_2 annually. Whilst the projected potential has not been fully realised, it is important to note that the installed capacity of the 11 gasifiers is 1,050 KW of which only 500 kW is currently functioning. As mentioned in Section 1, the full technical potential of the project is yet to be realised. The project has faced a number of barriers. However, all 11 gasifiers are expected to be operational before the December 2012.

If the full technical potential of the project is assumed, annual reductions of CO_2 could be much higher than indicated by this analysis.

3. CARBON SAVINGS FROM AFFORESTATON AND REFORESTATION

This chapter presents the analysis of carbon savings achieved from the cultivation of energy plantations, and the key findings of this assessment.

3.1 Introduction

According to the Forest Survey of India (FSI), 'all lands more than one hectare in area, with a tree canopy density of more than 10% can be defined a forest'. Afforestation is the establishment of a forest or stands for trees in an area where the preceding vegetation or land use was not forest. Reforestation is the reestablishment of forest cover either naturally or artificially, usually maintaining a similar forest type to the preceding land area, and done promptly after the previous stand or forest was removed. The importance of both afforestation and reforestation is in restoring forests, increasing carbon capture and sequestration, and assisting in preservation of biodiversity.

The forest sector could be a source or a sink of carbon. Forest carbon stock includes biomass and soil carbon pools. Biomass carbon can be further disaggregated into aboveground and belowground biomass and dead organic matter. Change in forest carbon stock between two time periods is an indicator of the net emissions of CO_2 from the sector.

India has been implementing an aggressive afforestation programme. The country initiated large-scale afforestation under the social forestry programme starting in the 1980's. This includes community woodlots, farm forestry, avenue plantations and agro-forestry.

Afforestation and reforestation in India are being carried out under various programmes, namely social forestry initiated in the early 1980s, Joint Forest Management Programme initiated in 1990, afforestation under National Afforestation and Eco-development Board (NAEB) programmes since 1992, and private farmer and industry initiated plantation forestry.

They are typically carried out on two types of land:

- Common and forest lands; and
- Farm lands.

Afforestation of common lands and forest lands

Vacant common land and forest land have been utilized for biomass development. The planting types followed are;

1. Energy Plantations: These plantations are raised in community land and forest land which are devoid of vegetation. The main focus is to have high density plantations of mixed fast growing species.

2. Assisted Natural Regeneration (ANR): In this model, the existing root stock is protected from biotic interference like grazing, fire, illicit felling etc. by physical and social fencing thus allowing the vegetation to revive on its own. The natural stands are assisted by cultural operations and enrichment planting.

3. Avenue Plantations: Land available on either sides of the village road is made use of to create avenue plantations.

4. Clonal Orchards: High-yielding clonal orchards are established in the project area to produce faster and cheaper biomass. These clonals yield more than double the quantity of biomass as compared to regular common varieties.

Afforestation of farm lands (Tree Based Farming)

Tree based farming activity is promoted on private farm land so as to grow biomass on a sustainable basis to ensure steady supply to the local gasifier plant. There are usually two types of plantations under tree based farming (TBF) – Bund planting and Block - planting.

For this purpose, fast growing trees which can be harvested repeatedly like Eucalyptus, Casuarina, Acacia auriculiformis, Albizzia, Cassia siamea, Glyricidia, Sesbania, etc. are planted. TBF has three primary models as follows:

1. Agro-horti Forestry (AHF): Plantation involve intercropping of fruit yielding trees with agricultural crop and planting of forestry species around the boundary to produce fruit, fuel, fodder, green manure and small timber

2. Agro Forestry (AF): Plantations involve planting of forestry species on the boundaries of crop land

3. Farm Forestry (FF): involves planting of fuel wood species in wood lots of fallow and wastelands. This also helps farmers in drought proofing

Selection of Carbon Pools and Non-CO2 Greenhouse Gases

There are four carbon pools in such activities – aboveground biomass, belowground biomass, dead organic matter that includes dead wood and litter, and soil organic carbon. The carbon pools are defined as follows:

1. Aboveground biomass: All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage. In cases, where forest understorey is a relatively small component of the aboveground biomass carbon pool, it is acceptable to exclude.

2. Belowground biomass: All living biomass of live roots. Fine roots of less than (suggested) 2 mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.

1. Dead organic matter: This pool includes dead wood as well as litter.
2. Litter: Includes all non-living biomass with diameter less than a minimum diameter chosen (for e.g., 15 cm), dead and in various states of decomposition above the mineral or organic soil. Live fine roots (of less than the suggested diameter limit for below ground biomass) are included in litter, when difficult to distinguish.
3. Dead wood: Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter.
4. Soil organic carbon: Includes organic carbon in mineral and organic soils, including peat up to 30 cm depth. Live fine roots (< 2 mm) are included with soil organic matter where they cannot be distinguished from it empirically.

Carbon pools are used to determine the total carbon sequestration potential available from the plantations under the BERI project. The following sections elucidate the methodology used to assess the potential carbon savings and highlight key results.

3.2 Methodology

The carbon sequestration and the carbon stock and flow in the project area were estimated. Afforestation and reforestation activities have been prevalent in the project area since inception. Close to 3,000 ha of land have been planted and the mitigation benefits are likely to be significant.

The steps followed to conduct the study are discussed in the following sections. The outline methodology is further highlighted in Box 3.1 below:

Step 1: Project boundary

The BERI project has been implemented in the Tumkur District of Karnataka State, India. Afforestation activities have been implemented in 5 taluks of Tumkur district spanning 26 villages (Annex 2). The project boundary is defined as primary and secondary project boundary.

The primary project boundary is the geographic boundary subjected to project intervention or activities i.e. planting, management and protection. The project boundary for the plantation activity on common and forest lands are identified at the parcel level by the land survey numbers (Annex 3)[10]. The records of BERI plantations are available with the Tumkur Forest Department. Annex 3(a) to 3(b) gives the project location and project boundary details of plantations on Forest Department lands and Tree Based Forestry on private lands. The project boundary is identified by the farmer's name, survey number, and area and year of planting. The secondary project boundary includes project boundary area subjected to project activities as well as locations and land use systems impacted or experiencing leakage[11] due to shifting of land conversion or biomass extraction or livestock grazing outside the project boundary. Thus taking into account the possible leakage or other impacts of the project activity, the secondary project boundary encompasses the village boundary.

Step 2: Key afforestation activities under the BERI project

Different forestry projects have different direct human-induced changes in carbon stocks and non-CO_2 greenhouse gases. Under the BERI project, the forestry plantation models under the various land categories are as given in Table 3.1.

[10] A reference to sampling

[11] Large scale use of carbon sequestration helps to avoid increasing GHG emissions in the project area. There is however a possibility that leakage from surrounding areas though activities such as biomass extraction could negate any benefits from the project.

Table 3.1: Types of forestry activities under BERI project

Options	Plantation Type	Land Category
Afforestation of common land and forest land		
Plantation forestry	I) Energy Plantation II) Clonal Orchard III) Avenue Plantation	Degraded common and forest land
Regeneration	I) Assisted Natural Regeneration	Forest land with good rootstock
Tree-based farming		
Bund Planting	I) Agro-horti Forestry II) Agro Forestry	Cropland lands
Block Planting	I) Farm Forestry	Fallow lands

Source: BERI (2010)

Plantation area under BERI project

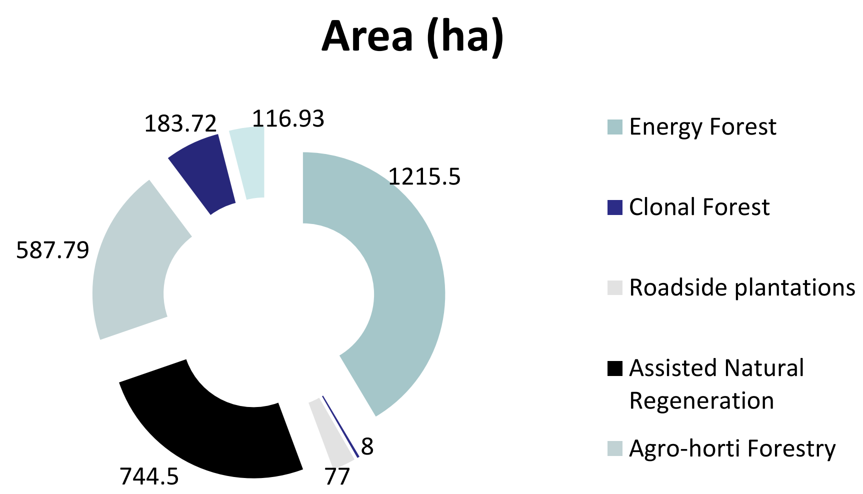
The total area afforested/reforested under the project is 2,933.44 ha (Table 3.2) of which 70% accounts for plantations under common and forest lands and the remaining 30% under tree based farming (Table 3.2). The area under afforestation on common and forest lands is 2,045 ha of which energy forestry account for 60% of the area, followed by 36% under assisted natural regeneration. The tree based farming is dominated by agro-horti forestry accounting for 66% of the area followed by agro forestry (21%) and farm forestry (13%).

Table 3.2: Area afforested under BERI project according to different activities

Plantation Type	Area (ha)
Afforestation on common and forest lands	
Energy Forest Model	1215.50
Clonal Forest Model	8.00
Roadside plantations	77.00
Assisted Natural Regeneration	744.50
Total	2045.00
Tree Based Farming	
Agro-horti Forestry	587.79
Agro forestry	183.72
Farm Forestry	116.93
Total	888.44
Grand Total	**2933.44**

Source: BERI (2010)

Figure 3.1: Area afforested under BERI



Step 3: Identification of relevant carbon pools to be monitored

The decision on which carbon pools to measure is critical to inventory design. In general, all pools which are large and subject to substantial change over the project life should be measured. Those that are small or very slow to change may not be measured (IPCC GPG, 2003). The decision depends on expected rate of change, magnitude and direction of change, availability and accuracy of methods to quantify change, and cost involved in measurements.

Table 3.3: Carbon pool considered and monitored in BERI project

Project type	Dominant land use component	Aboveground biomass	Belowground biomass	Woody litter + Dead wood	Soil organic carbon
Plantations	Degraded lands	Y	Y	N	Y
Agro-forestry	Cropland	Y	Y	N	Y
Regeneration	Degraded Forest lands with rootstock	Y	Y	N	Y

Y = Measured; N = Need not be measured

The project activity is on degraded forest lands and for TBF on fallow lands. Hence the most important carbon pools to be considered are aboveground biomass, below ground biomass and soil organic carbon. The plantations are 5-6 years old. Hence dead wood and litter is not a major carbon pool and can be ignored.

Step 4: Designing a sample framework

The total area afforested/reforested under the BERI project is 2933.44 ha. There are four options for sample design - complete enumeration, simple random sampling, systematic sampling and stratified random sampling. For the BERI project, the stratified random sampling was chosen, which is the most precise option for a certain cost.

The stratification has been based on the plantation model, vegetation and year of planting/age of the planting. Plantation wise, year-wise plantations details for afforestation and TBF is as given in Table 3.4 and 3.5. Representative samples have been taken in all the ranges and villages thus ensuring that spatially all the variations are captured.

Table 3.4: Model wise and year wise area plantation details for afforestation on common and forest lands

Range	Model	2003	2004	2005	Grand Total
Gubbi	Energy Forest	80	150	175	405.0
	Avenue Plantation	1		4	5.0
Koratagere	ANR	132	5		137.0
	Clonal	1			1.0
	Energy Forest	31	35	75	141.0
	Avenue Plantation	10		6	16.0
Madhugiri	ANR	10.5	190	200	400.5
	Energy Forest	12.5	180	180	372.5
	Avenue Plantation	9	3.5	12	24.5
Sira	ANR	50	67	90	207.0
	Clonal		2	5	7.0
	Energy Forest	20	45	150	215.0
	Avenue Plantation	6	6.5	12	24.5.0
Tumkur	Energy Forest			82	82.0
	Avenue Plantation	7			7.0
Total	ANR	192.5	262	290	744.5
	Clonal	1	2	5	8.0
	Energy Forest	143.5	410	662	1215.5
	Avenue Plantation	33	10	34	77.0
Total Area		**370**	**684**	**991**	**2045.0**

Table 3.5: Model wise and year wise area plantation details for TBF

Range	Model	2005-2006	2004-2005	2003-2004	Total
	AHF	156.00	26.00	0.00	182.00
Gubbi	AF	16.00	19.20	0.00	35.20
	FF	4.00	3.20	0.00	7.20
	AHF	21.90	14.24	34.80	70.94
Koratagere	AF	27.60	25.40	8.40	61.40
	FF	33.40	4.40	4.40	42.20
	AHF	2.33	2.99	0.00	5.32
Madhugiri	AF	0.94	2.51	0.00	3.46
	FF	7.06	1.15	0.00	8.21
	AHF	79.62	55.71	0.00	135.33
Sira	AF	29.36	22.10	0.00	51.46
	FF	29.70	6.62	0.00	36.32
	AHF	144.20	50.00	0.00	194.20
Tumkur	AF	19.40	12.80	0.00	32.20
	FF	14.20	8.80	0.00	23.00
	AHF	**404.05**	**148.94**	**34.80**	**587.79**
Total	**AF**	**93.30**	**82.01**	**8.40**	**183.72**
	FF	**88.36**	**24.17**	**4.40**	**116.93**
Total Area		**585.71**	**255.12**	**47.60**	**888.43**

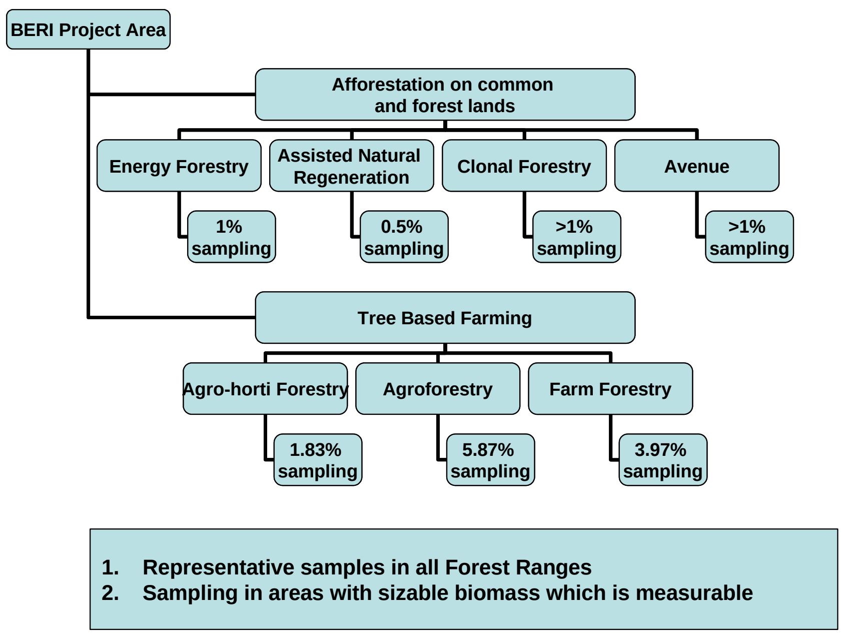
Source: BERI (2010)

Systematic sampling

The sampling followed that of the 2005 study titled 'Estimation of Carbon Sequestration in the Project Area'[12]. The number of plots selected and locations were identical to the study conducted in 2006. This was done so as to ensure easy comparison of the total carbon sequestration during different periods of the project.

All the models under plantations under common and forest lands and the TBF were covered. Representative samples were laid in all the forest ranges, villages encompassing all the forestry models. Since the plantations were established since 2003, sampling was done in areas with sizable measurable biomass. The random stratified sampling was followed. Care was taken to maintain plot distance to avoid between plot correlations.

Fig 3.1: Sampling strategy to assess carbon stock under Land Use Change and Forestry sector under BERI project



The various parameters to determine if the sample plots were optimal are as given in Table 3.6[13].

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[12] The study was conducted was titled, Estimation of Carbon Sequestration in the Project area - From the Forestry Sector. It was conducted by Sudha, P.,Hamedulla Khan and Murthy, I.K from the Asian Nature Conservation Foundation, Bangalore

[13] For detailed sampling procedures refer to the previous study; Sudha., P et al (2005), Estimation of Carbon Sequestration in the Project area - From the Forestry Sector

Table 3.6: No. of plots to be laid according to the fixed precision levels and plots laid on field to determine aboveground biomass

Models	No. of Plots based on the fixed precision levels	No. of plots laid for field studies in 2010	Plot size	Area of each plot (ha)	Total area of sample plots (ha)
Energy Forest Model	58	45	25m x 20m	0.05	2.25
Assisted Natural Regeneration	12	13	25m x 20m	0.05	0.65
Clonal Forest Model	4	6	25m x 20m	0.05	0.30
Avenue Plantations	6	7	1 KM x 3	0.3	2.10
Agro-horti forestry	7	26	1-acre	0.4	10.40
Agro Forestry	7	29	1-acre	0.4	11.60
Farm Forestry	22	33	25m x 20m	0.05	1.65
Total	**123**	**159**	**-**	**-**	**28.95**

Setting up Sample Plots

A 'nested' sampling approach was adopted for measurement of biomass component. Square plots were preferred. The sample sizes followed were as follows:

- Trees (diameter 30 cm and height 1.37 m); square plots of 25 X 25 m.
- Sub-plots of 5 X 5 m within the larger plots for trees

Sample plots were selected by the optimum plot allocation approach based on fixed precision levels. Care was taken to avoid selecting plots in areas with very dense or least vegetation.

Step 5: Measurement Techniques for Monitoring Carbon Pools

Inventory of forest carbon depends directly or indirectly on the estimation of biomass in sample plots. Different sampling strategies are likely to be required depending on the structure, composition and scale of the various stands involved; the specific objectives of inventory, the financial and other resources available. The underlying objective should however be to select a sampling method or a combination of methods that will yield the most efficient and reliable information at the required scale.

Aboveground biomass

This is one of the most important pools to assess for forestry projects. Several methods exist for estimation of biomass. The method followed for the estimation of above ground biomass is taking field measurements and applying species-specific allometric equations. This method involves morphometric measurements[14] of standing vegetation i.e. the stem, height, canopy etc. and using allometric equations[15] to estimate the biomass. This method is most commonly used to predict the mass of above- and belowground components of forests. These equations provide a relation between easily measurable parameters such as the diameter, height or basal area and tree biomass or carbon content. Biomass of trees was estimated using appropriate regression equations that are applied to tree measurements.

Quadrat plots were laid. The corners of the quadrat were marked and the GPS reading of all the four corners were noted. Measurements of all the trees within the quadrat were recorded. Only trees with diameter >30 cms and height >1.37 m were measured for the Girth Breadth Height (GBH). A tree below this diameter, especially in the TBF, the DBH was measured using calipers. Measurement of tree height is difficult, unlike DBH, especially, in a dense forest or plantation, with dense tree stems and overlapping tree

[14] Traditional morphometric data are measurements of size. i.e lengths, widths, masses, angles, ratios and areas

[15] Allometric equations are used to study mass of organisms. Specifically used in practical applications to the differential growth rates of the organisms.

crowns. Height data is an indicator of biomass and growth rate. To measure the height of a tree, a pole was marked at every ½ meter interval. The pole was kept aside the tree and measurement of the tree was determined.

Belowground Biomass

Methods for measuring and estimating aboveground biomass are relatively well established as compared to methods for belowground biomass, which are difficult and time-consuming. Currently no practical field method exists and actual quantification is very expensive when measured directly. Default root-shoot ratios have been used to estimate the below ground biomass. The commonly adopted method is the use of default root:shoot ratios. Below ground biomass was measured using regression equation for tropical forests as given in IPCC, Good Practice Guidance, 2006.

Soil Organic Carbon

Estimating soil organic carbon density (tC/ha) is crucial for forestry projects. To obtain an accurate inventory of organic carbon stocks in soils, three parameters must be measured; i) depth, ii)) bulk density, calculated from oven-dry weight of known volume of sampled soil, and iii) concentration of organic carbon within the sample. The Walkley Black method[16] was used to estimate the soil organic carbon content of soil.

Step 6: Measuring Carbon Stocks, Baseline and Actual

The steps outlined below for different carbon pools were used to calculate carbon stocks in trees.

Baseline Scenario

"Baseline net GHG removals by sinks" is the sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of the project activity. A baseline covers emissions from all gases, sectors and sources within the project boundary. It is the initial site condition before the project begins and it is necessary to assess the carbon stock change that would have occurred in the project area, if project activities were not implemented.

The land use systems identified in the BERI project area for baseline carbon stock are as follows:

- Common and forest lands on which afforestation was done

[16] The Walkley-Black method, used since the 1930's, uses chromic acid to measure the oxidizable organic carbon in a soil. The basic Walkley-Black oxidation relies upon the heat of solution of the sulfuric acid and water for the reaction. This method incompletely oxidizes the organic carbon and a correction factor of 1.3 is commonly applied to the results to adjust the easily oxidizable carbon to total organic carbon.

- With good rootstock on which assisted natural regeneration was implemented
- Degraded lands on which energy plantations, clonal plantations were implemented
- Avenue plantations

- Farmers' land on which tree based farming has been implemented

Estimation of Baseline GHG Removals by Sinks

Biomass

To estimate baseline GHG removals by sinks it is necessary to estimate the initial and periodic carbon stocks under baseline or without project scenario. This involves estimating the carbon stock and change in vegetation and soil. The method followed for baseline carbon stock was as follows:

- In each of the stand-types determined above, plots for sampling were selected.
- The methods, parameters, sampling design, selection of plot size and number of plots, laying of plots, measurement and recording of data and biomass or carbon estimation procedures was as done for project scenario.
- Based on the stratification and required number of sample plots for minimum error, the area of sampling was selected.
- Quadrats were laid and measurements of trees were taken. Soil samples were collected.
- Since the project was initiated while carbon monitoring was initiated, measurements for baseline were done on adjacent lands with similar pre-project conditions.

Random sampling was employed to sample for vegetation and soil organic carbon (SOC) as the land categories are degraded lands and fallow cropland with negligible above- and belowground carbon pools in the baseline scenario.

Table 3.7: Baseline carbon stock for land categories under BERI project

Land Category	Models implemented	Area (ha)	Baseline Biomass Stock (t dm/ha)	Baseline Carbon stock (tC/ha)	Baseline Carbon stock for the area (tC)	Baseline CO_2 stock for the area (tCO_2)
Forest lands with good root stock	- Assisted Natural Regeneration	744.5	0.34	0.17	127	464
Degraded lands	- Clonal - Energy Forestry	- 8.0 - 1215.5	0.14	0.07	1 85	4 312
Roadside	- Avenue Plantation	- 77.0	0.00	0.00	0	0
Farm lands	- Agro-Horti Forestry - Agro Forestry - Farm Forestry	- 888.44	0.00	0.00	0 0 0	0 0 0
Total					**213**	**780**

Source: Sudha, P et. al (2005)

They baseline carbon biomass stock (above and below ground biomass) are either insignificant or form a very small proportion of the total carbon pool in degraded lands[17] (Table 3.7). The average biomass carbon pool in the baseline scenario is 0.07 tC/ha or 0.26 tCO_2/ha. Carbon removals in the baseline scenario need not be measured subsequently, as it is insignificant. Hence a steady or fixed baseline can be assumed. The following case can be assumed for the BERI project for subsequent carbon stock monitoring, as the baseline carbon stocks are negligible.

Baseline GHG removals for the project period (tCO_2) = Baseline GHG removals at year 0 = C_{BL}

Overall, the GHG removals by sinks for the baseline scenario is 780 tCO_2.

Soil Organic Carbon

Information on the baseline soil organic carbon was limited. The information available is highlighted in table 3.8. Agro-horti and agro-forestry models were not available since at

[17] The baseline carbon stock indicated in this section refers to aboveground biomass only. Baseline figures for belowground biomass were not taken into consideration since the values were found to be insignificant and were subsequently removed from the analysis.

the time it involved only bund planting and the major management practice is agriculture.

Table 3.8: Baseline Soil organic carbon of plantations under BERI project

Model	Baseline Soil Organic Carbon (tC/ha)
Plantations on common and forest lands	15.64±10.45
Tree based Farming	11.70±6.57

Source: Sudha, P et. al (2005)

Project Scenario

Biomass

Aboveground Biomass

Generalized or allometric biomass regression equations were used to estimate aboveground tree biomass. Species specific and generic equations have been developed by Forest Survey of India (FSI, 1994), based on diameter at breast height and height of tree for different regions in India. The equation was used only for those that are in the specified diameter class or range. The volume equation used for the study is given in Annex 4. Wood density factor was used to convert volume to stem biomass. Species specific wood density was used to convert volume to biomass. The species specific wood density was obtained from the agro-forestry tree database of ICRAF. The web source is http://www.worldagroforestry.org/sea/products/AFDbases/WD/asps/DisplayDetail.asp ?SpecID=11. The total biomass stock was obtained by summing the biomass of individual trees in each plot and multiplied with the expansion factor to obtain biomass per hectare. Dry weight of biomass was estimated by deducting the moisture content. Based on the IPCC good practice guidance, 50% of biomass is taken as the carbon content of biomass. Expansion factor was used to convert biomass values from per plot to per hectare as follows:

$$Expansion \cdot factor = \frac{10000.m^2}{Area \cdot of \cdot plot \cdot (m^2)}$$

Annex 4 indicates specific equations of trees and other wood density according to species.

Belowground Biomass

Root biomass can account for 10 to 40% of the aboveground biomass. Thus, it is useful to estimate root biomass, as significant carbon could be stored in root biomass. The measurement of aboveground biomass is relatively established and simple. Belowground biomass, however, can only be measured with time-consuming methods. Consequently it is more efficient and effective to apply a regression model to determine belowground biomass from knowledge of biomass aboveground. The following regression model was used to estimate the belowground biomass.

$$BBD = \exp(-1.0587 + 0.8836 \times \ln ABD)$$

Where BBD = belowground biomass density in tons per ha (t/ha)

ABD is the aboveground biomass density (t/ha)

Applying the equation allows an accurate assessment of belowground biomass. This is the most practical and cost-effective method to determine biomass of roots.

Carbon stock

The carbon stock of standing biomass and below ground biomass was estimated at the plot level. The carbon stock for the different components were summed within plots to give per plot carbon stock in t/ha. The plot level results were then averaged to give mean for the stratum. The carbon stock for baseline and project area was calculated separately as follows.

Total carbon stock per ha (tC/ha) $C_{ha} = C_L + C_{Soils}$

Where: C_L = Carbon removals by sinks in living biomass (includes above- and belowground biomass) (tC/ha); C_{Soils} = Carbon removals by sinks in soils; (tC/ha)

Table 3.9: Productivity of aboveground biomass of various models in BERI project area

Model	Productivity (t/ha/yr)	Productivity (t dm/ha/yr)	Productivity (Mean ± SD) (tm /ha/yr)-2010*	Increment (t/ha)
	Plantation on common and forest lands			
Energy forestry	2.59±1.05	1.81 ± 0.74	2.72 ± 0.79	0.91
Assisted natural regeneration	1.67±1.28	1.17±0.9	14.22 ± 7.70	13.05
Clonal forestry	3.50±1.18	2.45±0.83	2.79± 0.76	0.34

Avenue plantations	0.97±0.84	0.68±0.59	10.97 ± 5.54	10.29
	Tree Based Farming			
Agro-horti Forestry	0.32±0.35	0.22±0.25	9.84 ± 2.21	9.62
Agro Forestry	031±0.32	0.22±0.22	8.10 ± 2.5	7.88
Farm Forestry	3.99±1.77	2.79±1.24	3.10 ± 0.41	0.31

Source: Calculations (2010); *@30% moisture content

The productivity of the various plantation models were determined based on field studies (Table 3.9). The standing biomass for various models and age stands were calculated by multiplying the productivity with age and area (Table 3.9).

As the project was divided into multiple strata, the carbon stock was calculated for individual strata. The carbon stock per unit area was multiplied by the area of the project and the age of the plantation to produce an estimate of the total carbon stock (tC) for the stratum.

Total carbon stock for the stratum (tC) Cs = $\sum_{i=1}^{n} Li * C_{iha}$

where: Li is the area under each stratum 'i' to 'n' (area in ha); C_{iha} is the carbon stock per ha for stratum 'i' to 'n' (tC/ha)

Table 3.10: Carbon stock of aboveground biomass (tC) for the project area.

Model	**8 years (2003 -04)**	**7 years (2004-05)**	**6 years (2005-06)**	Total
	Plantation on common and forest lands			
Energy forestry	1054.93	4536.10	4938.81	10529.84
Assisted natural regeneration	2881.59	10653.40	14579.25	28118.12
Clonal forestry	58.25	0	17.72	75.97
Avenue plantations	53.54	0	680.52	734.08

Total	**4048.31**	**15189.5**	**20216.3**	**39454.08**
		Tree Based Farming		
Agro-horti Forestry	0	385.56	1315.21	1700.77
Agro Forestry	0	167.81	372.03	539.83
Farm Forestry	0	119.46	872.44	991.90
Total	**0**	**672.83**	**2559.68**	**3232.50**
Grand Total				**42690.50**

The below ground biomass was determined using the regression equation. The total carbon stock from living biomass for the project area (tC) is given in Table 3.11.

Table 3.11: Carbon stock of living biomass under various carbon pools under the BERI project

Model	Above-ground biomass(tC)	Below -ground biomass(tC)	Total (tC)
	Plantation on common and forest lands		
Energy forestry	10529.84	1146.53	11678.58
Assisted natural regeneration	28114.12	2730.51	30937.42
Clonal forestry	75.97	14.69	85.06
Avenue plantations	734.08	108.98	1021.10
Total	**39454.01**	**4000.70**	**43722.16**
		Tree Based Farming	

Agro-horti Forestry	1700.77	228.97	1929.74
Agro Forestry	539.83	83.06	622.89
Farm Forestry	991.90	142.18	1134.08
Total	**3232.50**	**452.21**	**3686.71**
Grand Total	**42686.50**	**4454.91**	**47141.41**

The above table indicates the total above and below ground biomass in the BERI project area. The total carbon stock of living biomass under various carbon pools is 47,141 tC

Soil Organic Carbon

There are many processes that determine the direction and rate of change of SOC when vegetation and soil management practices are changed. The most important reasons are i) increasing the input rates of organic matter ii) changing the decomposability of organic matter inputs that increases organic matter, iii) placing organic matter deeper in the soil indirectly through enhancing surface mixing by soil organisms and iv). enhancing physical protection through either intra-aggregate or organo-mineral complexes. Conditions favoring these processes occur generally when soils are converted from cultivated use to permanent perennial vegetation. In the BERI project, only under farm forestry there is such conversion. Practically, the variation in the rates of SOC change can be attributed to a lack of consistent initial conditions resulting from spatial heterogeneity. To obtain higher precision predictive capacity of detecting changes in SOC, repeated monitoring and sampling should be done at the same project site.

The study of SOC accumulation uses three different sets of data. There is baseline information, information from a study conducted in 2004 and the current project study. Comparable the baseline, mid-project and project area study has not provided accurate results. The accumulation of SOC takes a longer duration than in vegetation. Since data has not been collected in a yearly fashion, an assessment of yearly increase in SOC for the various models is not possible. Repeated soil analysis at the same project site at every 5 years interval will give a comparable value of the incremental SOC due to project intervention.

To estimate soil organic carbon, soil samples at depth of 0-30 cm was collected. Bulk density was estimated and soil organic carbon content was estimated in the laboratory using the Walkley-Black method. Soil samples from wastelands and fallow lands representing baseline scenario were collected. A composite soil sample from multiple soil samples collected from four corners of the tree quadrat was prepared for analysis. The SOC was estimated for the project area in the year 2003 and year 2010. The variation in the SOC of the project area in 2004 compared to the SOC in the year 2010 is the increment in SOC due to project activity.

Accordingly, based on the age of the plantations, the SOC increment has been calculated for the total area (Table 3.12).

Table 3.12: Soil organic carbon increment in the project area

Model	**Base line soil organic Carbon for project area in-2003 (tC)**	**Soil organic Carbon for project area in-2010 (tC)**	**Net Soil organic Carbon for project area in-2010 (tC)**	**Mean Soil Organic Carbon gain in 2010 (tC/ha)**	**Mean Annual increment(MAI) in Soil Organic Carbon in 2010 (tC/ha/yr)**
Plantation on common and forest lands					
Energy forestry+Clonal	19319.07	31105.29	11786.23	9.63	1.38
Assisted natural regeneration	13639.24	18374.26	4735.02	6.36	0.91
Avenue plantations	1936.55	1714.02	-222.53	-2.89	-0.41
Tree Based Farming					
Agro-horti Forestry	11914.50	11461.91	-452.60	-0.77	-0.11
Agro Forestry	3724.00	4322.93	598.93	3.26	0.47
Farm Forestry	2626.25	2912.73	286.48	2.45	0.35

Since there are multiple strata, the carbon stock for all the stratums was summed to obtain the carbon stock of the project area as follows.

If more than one stratum,

Carbon stock for the total area (tC) Cts = $C_{s1} + C_{s2} + C_{s3}\ldots\ldots\ldots + C_{sn}$

Cs = Carbon stock for stratum 1 to n

Table 3.13: Carbon pool increment in the project area

Model	Area (ha)	Above-ground biomass (tC)	Below - ground biomass(tC)	Soil Organic Carbon (tC)	Total (tC)	Total (tCO_2)
	Plantation on common and forest lands					
Energy forestry	1215.5	10529.84	1148.74	11786.23	23464.81	85881.2
ANR	744.5	28118.12	2819.3	4735.02	35672.44	130561.1
Clonal forestry	8	75.97	9.09	67.13	152.19	557.0154
Avenue plantations	77	734.08	287.02	-222.6	798.5	2922.51
Total	**2045**	**39458**	**4264**	**16365.78**	**62030.92**	**219921.9**
				Tree Based Farming		
Agro-horti	587.79	1700.77	1362.42	-452.6	2610.59	9554.759
Agro Forestry	183.72	539.83	566.17	598.93	1704.93	6240.044
Farm Forestry	116.93	991.9	137.36	286.48	1415.74	5181.608
Total	**888.73**	**3232.5**	**2065.95**	**430.23**	**5728.68**	**20976.41**
Grand Total	**2933.44**	**42690.51**	**6330.1**	**16798.59**	**65819.2**	**240898.27**

There is a lot of uncertainty regarding soil organic carbon. Considering only aboveground and below ground as suggested by the UNFCCC, the total carbon sinks ((tCO_2) ABG and BGB) is 49020 tC or 179903 tCO_2. Considering also the soil organic carbon the total tCO_2 sequestered so far is 240898 tCO_2 (Table 3.13).

Step 7: Estimation of net CO_2 removals by sinks for the project area

"Actual net greenhouse gas removals by sinks" is the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in emissions of GHGs measured in CO_2 equivalents by the sources that are increased as a result of the implementation of the project activity, while avoiding double counting, within the project boundary, attributable to the project activity.

It is therefore essential to estimate the carbon sinks and non-CO_2 emissions in the project boundary periodically to estimate the actual GHG removals by sinks due to project activity. Methods, techniques and models are available and are being successfully used to estimate the changes in carbon stocks in different land use systems. The approach most commonly used to estimate carbon stocks (in biomass and soil) is based on calculating the difference in carbon stocks between a project scenario and its baseline at a given point of time. The approach is referred to as "stock change method" (Brown et al., 2000).

To estimate the actual net GHG removals by sinks the carbon stocks in the carbon pools within the project boundary, minus the increase in emissions of the GHG (CO_2 equivalents) by the sources due to project activity.

CPL = (Cptc) * 44/12 – ECO_2eq

where: CPL = Actual net GHG removals by sinks (tCO_2)

Cptc = Carbon stocks under project scenario (tC)

ECO_2eq = Non-CO_2 equivalent emissions from the project area from Equation G5

44/12 = Conversion factor from carbon to CO_2

The CO_2 pool within the project boundary as calculated is 240898 tCO_2 for the project area of 2933.44 ha. The increase in emissions of the GHG by sources due to project activity is 0. Hence the actual net GHG removal by sinks is 240898 tCO_2.

Calculation of uncertainty

To reduce uncertainty, it is essential to derive confidence intervals by applying a quantitative method to existing data. Confidence intervals at given confidence levels provide a minimum basis for a simple quantitative estimate of uncertainty. To remain consistent with GPG (2000), uncertainties have been estimated at 95% confidence limits.

There are two methods for calculating the total uncertainty for a project activity. Here the simple error propagation has been used to calculate uncertainty. The overall uncertainty for actual net GHG removals by sinks can be assessed as follows (IPCC GPG, 2003):

$$U_{total} = \sqrt{U_1^{\ 2} + U_2^{\ 2} + ...U_n^{\ 2}}$$

Where: Total = percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total, expressed as %

Ui = percentage uncertainties associated with each of the quantities, i = 1, …, n

The following steps were followed to calculate the uncertainty associated with calculations of GHG removals for the BERI project area.

Step 1: The plot level results of increment of biomass for living trees, above- and belowground in permanent plots were averaged to give mean and 95% confidence intervals for the stratum. The mean for each of the strata is given in Table xx. The CI was calculated using the following equation.

$$\sqrt{}$$

where, [95%CIveg] = 95% confidence interval for vegetation, [95%CIsoil] = 95% confidence interval for soil.

The confidence level at the stratum level based on plot information is shown in Table 3.14.

Table 3.14: Confidence level calculation for the project area

Model	**Total area (ha)**	**Total No. of samples**	**Standard deviation (tC/ha)b**	**Confidence level (tC/ha)**
Energy forestry	1215.50	45	0.40	
Assisted natural regeneration	744.50	13	1.82	
Clonal forestry	8.00	6	0.76	
Avenue plantations	77.00	7	0.98	
Agro-horti Forestry	587.79	26	0.31	
Agro Forestry	183.72	29	0.36	
Farm Forestry	116.93	33	0.90	

Step 2: The project has been analyzed at multiple strata. The confidence level for the project area based on the strata level CI is as follows:

Total 95% CI =

$$\sqrt{95\%CI_{EF}{}^{2} + 95\%CI_{ANR} + 95\%CI_{CF}{}^{2} + 95\%CI_{AVF}{}^{2} + 95\%CI_{AHF}{}^{2} + 95\%CI_{AF}{}^{2} + 95\%CI_{FF}{}^{2}}$$

where: [95%CIs1] = 95% confidence interval for stratum 1, stratum 2, etc. for all strata measured in the project.

$$\sqrt{0.11^2 + 0.24^2 + 0.36^2 + 0.21^2 + 0.05^2 + 0.04^2 + 0.29^2}$$

= 0.58 tC/ha

Step 3: Finally the total uncertainty in carbon stocks per unit area is then multiplied by the area of the project or entity to produce an estimate of the total change in carbon and converted to tons of CO_2 equivalent by multiplying by 3.67.

Total uncertainty = 0.58 x 2933.44 ha = 1691 tC x 3.67 = 6201 tCO_2/ha

THUS THE UNCERTAINTY AT 95% CONFIDENCE LEVEL IS 16,466±6201 tCO_2 FOR THE PROJECT AREA

Step 8: Estimation of carbon stock in extraction

One last step in calculating the net carbon benefit from forestry involves discounting the biomass stock extracted for fueling the biomass power plants on the project site. As mentioned before, all plantations under the BERI project are used as feedstocks grown specifically for the purpose of energy production. Wood from these plantations are harvested and then used in the biomass power plants to generate electricity.

It is critical to incorporate this factor into calculations of net CO_2 removals under the BERI project.

The biomass gasifiers at BERI function at a wood consumption rate of 1.2 tonnes of wood per MWh[18]. Information from field visits to the BERI project site suggests that the total wood harvested for the power plants is approximately 2 tonnes of wood per MWh[19]

With a total of 457 MWh of electricity produced, it can be assumed that the total amount of wood harvested for the gasifiers will be 914 tonnes of biomass extracted. Converting this to carbon stock gives a total 457 tC or 1676 tCO_2 in extraction. This would have to be discounted in the calculations thus far to arrive at the overall net carbon benefit from the afforestation activities.

The CO_2 pool within the project boundary as calculated is 640598 tCO_2 for the project area of 2933.44 ha. The increase in emissions of the GHG by sources due to project activity is 0 and 1676 tCO_2 is extracted for the purposes of the biomass gasifiers. Hence the actual net GHG removal by sinks is 239222.3 tCO_2.

3.3 Key Findings

The BERI project has instituted afforestation of common lands and forest lands in addition to promoting tree based farming. These activities generate significant carbon pools that contribute to mitigating GHG emissions from the BERI project. There are four carbon pools in such activities – aboveground biomass, belowground biomass, dead

[18] See CGPL (2010)

[19] This includes for losses during transportation, wastage, and inefficient harvesting among others.

organic matter that includes dead wood and litter, and soil organic carbon. Furthermore, a certain amount of wood is extracted for functioning of the biomass gasifiers and this amount needs to be subtracted the overall carbon pools that determine the sequestration benefits of the project.

Overall, 2933.44 ha of forest and farm land have been cultivated since inception of the BERI project. Field visits and subsequent calculations have indicated the total carbon pool increment (compared to the baseline) in the project area, to be 240898 tCO_2 (see table 3.15).

Table 3.15: Total carbon pool increment

	Above ground biomass (tC)	**Below -ground biomass(tC)**	**Soil Organic Carbon (tC)**	**Total (tC)**	**Total (tCO_2)**
Plantation on common and forest lands	39458	4264	16366	62031	219922
Tree Based Farming	3232	2066	430	5729	20976
Total	**42690**	**6330**	**16798**	**65819**	**240898**

Discounting for 1676 tCO_2 spent in extraction for the biomass gasifiers, the total net carbon benefit from the afforestation activities is estimated to be 239222 tCO_2.

It can be observed that plantation on common and forest lands contributes to nearly 91% of the total CO_2 sequestered. A study conducted in 2005 estimated the total CO_2 sequestered to be 16,466 tCO_2. The results of the study showed a similarly high percentage of CO2 savings from plantations on common and forest lands. The increase in CO_2 pool

4. CARBON SAVINGS FROM COMMUNITY BIOGAS UNITS

4.1 Introduction

Biogas technology, using local resources such as cattle dung and organic wastes, provides an alternate source of energy for cooking and lighting in rural areas and manure in the form of biogas spent slurry. When organic waste is stored in the absence of air, a microbial degradation process starts producing biogas, which is a mixture of 55% to 70% methane (CH4), which is the combustible component, 30% to 45% carbon dioxide (CO_2) and a small amount of hydrogen (H2). Biogas is a smokeless fuel offering an excellent substitute for kerosene oil, cattle dung cake, agricultural residues, and firewood, which are used as fuel in most of the developing countries.

Biogas is one of the oldest and most important renewable energy programmes implemented in India. India launched the national programme on Biogas Development during 1982. Both family-size biogas plants and community size biogas plants have been promoted through the programme. The purpose is to largely provide clean, safe and quality cooking fuel for rural households. Whilst the family biogas programme is considered most effective in terms of targets achieved, the community biogas programme have been said to have made slower progress. There is however limited literature to back this statement.

In rural areas, biogas plants mainly use cattle manure for cooking and lighting. Since the introduction of the programme over 4 million biogas plants have been installed, as of 2004, against a potential 12 million.

Biogas production from biomass is considered carbon dioxide neutral and therefore does not emit additional GHGs into the atmosphere. However, if biogas is not recovered properly, it will contribute to a GHG effect 20 times worse than if methane is simply combusted. Therefore, there is a real incentive to transfer biogas combustion energy into heat and/or electricity. Finally, biogas production from anaerobic digesters presents the additional advantage of treating organic waste and reducing the environmental impact of these wastes. It contributes to a better image of the farming community while reducing odor, pathogens and weeds from the manure and producing an enhance fertilizer easily assimilated by plants.

The calorific value of biogas is about 6 kWh/m3 - this corresponds to about half a litre of diesel oil. The net calorific value depends on the efficiency of the burners or appliances.

Biogas use, replacing conventional fuels like kerosene or firewood, allows for the conservation of environment. It therefore, increases its own value by the value of i.e. forest saved or planted. Biogas is able to substitute almost the complete consumption of firewood in rural households.

1 m^3 Biogas (approximately 6 kWh/m3) is equivalent to:

- Diesel, Kerosene (approx. 12 kWh/kg) 0.5 kg
- Wood (approx. 4.5 kWh/kg) 1.3 kg
- Cow dung (approx. 5 kWh/kg dry matter) 1.2 kg
- Plant residues (approx. 4.5 kWh/kg d.m) 1.3 kg
- Hard coal (approx. 8.5 kWh/kg) 0.7 kg
- City gas (approx. 5.3 kWh/m3) 1.1 m3
- Propane (approx. 25 kWh/m3) 0.24 m3

The biogas generated from small and medium sized units (up to 6m3) is generally used for cooking and lighting purposes. Large units and/or communal units produce this gas in large quantities and can be used to power engines and generators for mechanical work or power generation.

A recent study by Winrock, Nepal and others analyzing the earning potential through carbon credits found that each biogas plant can mitigate about five tCO_2 equivalent per year.

Furthermore, the widespread production and utilization of biogas is expected to make a substantial contribution to soil protection and amelioration. First, biogas could increasingly replace firewood as a source of energy. Second, biogas systems yield more and better fertilizer. As a result, more fodder becomes available for domestic animals. This, in turn, can lessen the danger of soil erosion attributable to overgrazing.

Thus overall, installation of community biogas units for generating cooking gas can have local environmental benefits (such as conservation of village trees and forests) and global environmental benefits (such as biodiversity conservation and CO_2 emission reduction). The fuel wood and forest conservation potential of the community biogas units installed by the BERI project is assessed in the following section.

4.2 Methodology

Biogas technology provides an excellent opportunity for carbon mitigation through the following:

- Replacing firewood for cooking,
- Replacing kerosene for lighting and cooking,
- Replacing chemical fertilizers

- Saving trees from deforestation

A survey of all existing biogas plants and their usage was conducted. A questionnaire was prepared[20] and the results evaluated to arrive at the carbon mitigation potential of biogas at BERI.

The key steps followed in assessing the carbon mitigation impact of community biogas units in the BERI project are assessing in the following sub-sections. Text box 4.1 presents the key stages followed in the analysis.

[20] See Annex I for the full questionnaire

Step 1: Business as Usual Scenario

An initial review of the project area in 2001 had indicated the prevalence of fuel wood for the purposes of cooking. Burning fuel wood leads to high emissions of CO_2 and methane in addition to causing human health problems. In the BAU scenario the total amount of fuel wood used for cooking before the installation and use of biogas units is assessed. This helps identify the carbon abatement potential from fuel wood conservation.

A review of project literature shows the absence of sufficient quantitative baseline information on the amount of fuel wood used before the inception of the project. To overcome this constraint, a detailed survey of the 171 households that participated in the community biogas programme was conducted. Each interviewee was requested to ascertain the average amount of fuel wood collected and used for the purpose of cooking on a daily/weekly/monthly basis. For households that are currently using biogas for cooking, the answers whilst hypothetical were found to be comparable to the amounts indicated by households currently not using biogas.

The data collected was collated and averaged to produce an approximate baseline scenario of the amount of fuel wood used by households for cooking.

Therefore, it is important to note that the data collected and used is subject to people's perceptions and as in any survey involving people, is subject to a significant error margin.

Overall, an average of 2.8 tonnes of fuel wood was estimated to be used per household per year for the purpose of cooking[21].

Step 2: BERI project Scenario

The project document dated March 2001 projects installation of 45 community biogas units in 24 village settlements with a total capacity of 4,000 m3/day for cooking gas and bio-fertilizer production.

Since inception, a total of 53 community biogas units have been installed in 31 village settlements covering 171 households. Each biogas unit was meant for three households. The energy derived from the biogas units was considered to be sufficient to meet a majority of cooking needs of an average five households.

On conducting a thorough survey of all 51 biogas units in the project, it was observed that over the years a large number of the biogas units are not being used. Unlike the biomass gasifiers, biogas units will only be effective with sufficient local community

[21] Annex 5 includes a detailed table of the total number of households surveyed and the results observed.

participation. Table 4.1 highlights the number of biogas units installed and currently in use[22]:

Table 4.1: Total biogas units installed

Clusters	Biogas units installed	No. of HH's served*	Biogas units currently in use	Biogas units previously used**
Gubbi	7	22	-	4
Tumkur	13	39	6	12
Sira	8	23	1	8
Koratgere	13	52	-	13
Madhugiri	12	35	3	12
Total	**53**	**171**	**10**	**49**

Source: HH Survey (2010); *The total number of households the biogas units were intended to serve; **Biogas units previously used have been discontinued for a number of reasons.

As indicated above, approximately 20% of community biogas plants are currently in use. A further 30% has been added to this figure; since a number of interviewees have indicated that the biogas units were used for varying lengths of time since installation (49 of the 53 installed units have been used in the past). Annex 5 contains detailed results.

Many households have since discontinued use due to problems such as:

- Insufficient co-ordination between the households sharing the community unit
- Insufficient supply of dung
- Land related conflicts
- Prevalence of readily available LPG
- Lack of understanding of the benefits

Thus any analysis of the total carbon mitigated from the project must factor the potential carbon mitigated from initial use of the biogas units. Keeping in mind, the above, the overall percentage of biogas units in operation was increased to 20% from 50% to include for those biogas units that were used in the past.

[22] For a detailed table of the household survey conducted see Annex 5

Currently the 10 biogas units in operation serve 27 households, with each unit catering to approximately 3 households. Assuming 50% of the biogas units currently working or having been used in the past, and using the original 171 households that were targeted by the programme, would signify approximately 86 households have availed the benefits of the biogas units provided by the BERI project thus far.

Within these households, a questionnaire was used to determine the total firewood used in comparison to the BAU scenario. Each interviewee was requested to ascertain the average amount of fuel wood collected and used for the purpose of cooking on a daily/weekly/monthly basis since the installation and use of the biogas units. Information collected from all these households was analysed and an average figure generated to be used in further calculations.

The interviewed households indicated that approximately 50% of cooking needs were met by the use of biogas on a daily basis. See table 4.2

Table 4.2: Total fuel wood conservation potential fuel wood use before biogas per day

	Qty of wood used without BG units (kg/day)	**Qty of wood used with BG units (kg/day)**	**Qty of wood saved (kg/day)**
BERI project area	7.8	3.8	4.3

Source: Household Survey (2010)

Thus a total of 1.5 tonnes of firewood was saved per household annually due to the introduction of biogas for cooking.

Step 3: Carbon abatement from fuel wood conservation

The following equation was used to estimate the total carbon savings from the installation and use of community biogas units.

*Carbon emissions saved = Total fuel wood saved by using biogas - % wood from felling * Emissions factor*

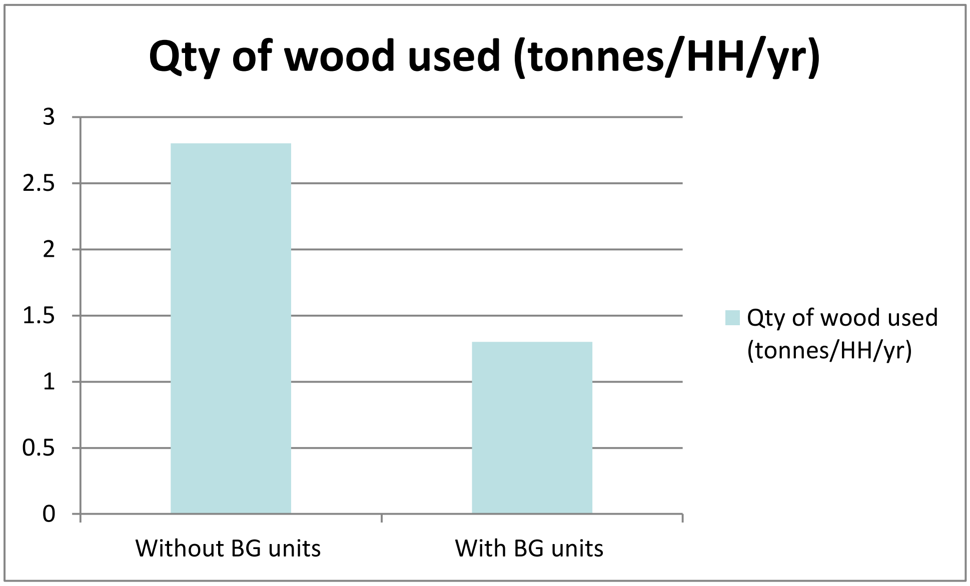
The following factors were taken into account while estimating the total carbon abatement from the substitution of fuel wood:

Total fuel wood saved by using biogas

This factor can be calculated by comparing the BAU scenario to the BERI project scenario. Comparing the information obtained in the above two sections,

The total fuel wood use reduced by the installation and use of the BERI project is calculated as 1.5 tonnes/household/year. Estimating this for the total 86 households benefiting from biogas, gives a total fuel wood conservation of 129 tonnes/year.

Figure 1.1 Annual fuel wood conserved per household



Unsustainable felling of wood

A large percentage of the wood extracted from the forests and farm lands tends to be done in an unsustainable way. It is important to discount this factor from the total fuel wood saved in order to arrive at a more accurate result. In this study, 33% of wood is assumed to be extracted unsustainably or damaged during extraction. This figure only pertains to wood from felling since wood collected from the ground is likely to grow back. The total wood extracted unsustainably is 42.5 tonnes/year.

Therefore the total amount of wood saved discounting for unsustainable extraction amounts to 86.5 tonnes/year.

Emissions factor

An emissions factor of 50% is used as per IPCC guidelines to calculate the total carbon stock in fuel wood. This is the conversion factor of wood to carbon stock.

Therefore substituting the above values in the equation above[23],

86.5 (tonnes/yr)* 0.5 * 3.67= 158.72 tCO_2/year

The total carbon emissions saved from the installation and use of biogas plants since inception can therefore be calculated to be 1428.5 tCO_2.

[23] Conversion of tC into tCO_2 is 3.67

4.3 Key Findings

The total fuel wood conservation for the nine years since project inception was estimated assuming 33% of fuel wood used is extracted in a non-sustainable way, through felling of trees and clearing of forests a plantations, which leads to net carbon emission. The net carbon emissions avoided by shifting to biogas would be 1428.5 tCO_2. Thus, apart from conservation of forests and biodiversity, fuel wood conservation programmes could lead to significant reduction in carbon emissions an conservation of forests and village tree sinks.

The total fuel wood use reduced by the installation and use of the BERI project is calculated as 1.5 tonnes/household/year. Estimating this for the total 86 households benefiting from biogas, gives a total fuel wood conservation of 129 tonnes/year. Discounting for unsustainable extraction amounts to 86.5 tonnes/year. Overall, the assessment found that the total carbon emissions saved from the installation and use of biogas plants since inception can therefore be calculated to be 1428.5 tCO_2.

The mitigation potential could be higher if all 53 community biogas plants installed were operational. The total fuel wood use reduced by the installation and use of the BERI project is calculated as 1.5 tonnes/household/year. Estimating this for the total 171 households benefiting from biogas, gives a total fuel wood conservation of 256.5 tonnes/year. Discounting for unsustainable extraction (33%) amounts to 171.8 tonnes/year of fuel wood savings. Substituting these values for those derived in the equation above, amounts to 2838.2 tCO_2 saved if all biogas plants were operational.

5. OVERALL CARBON SAVINGS FROM PROJECT ACTIVITIES

This section combines the results of the previous sections to present an estimate of the overall carbon savings that have been achieved as a result of the activities conducted under the BERI project.

Table 5.1: Total Carbon Abatement from BERI during the period 2001-2010 (Scenario 1)

Reduction from / Main components		Units
Biomass Gasification	Total biomass based power generated	457 MWh
	BAU - % likely to come from coal	53%
	Fossil fuel substituted	242 MWh
	CO_2 emissions saved per MWh	0.09 tCO2/MWh
	Total CO_2 emissions avoided	**198.44 tCO_2**
Forestry	Above-ground biomass carbon stock	156247.3
	Below-ground biomass carbon stock	23168.2
	Soil carbon stock	61482.8
	Carbon stock in extraction (for the gasifiers)	1676
	Total CO_2 emissions sequestered*	**239222.3 tCO_2**
Biogas	No. of community biogas units built	53
	% biogas units currently used/used in the past	50%
	No. of households benefited	86
	% of cooking needs met	50%
	Fuel wood conserved	129 tonnes/yr
	% of fuel wood from tree felling/damaging	33%
	Total CO_2 emissions avoided*	**1428.5 tCO_2**

Total	**Overall CO_2 emissions saved**	**240849.2**

Carbon savings from existing measures can be broken down into three main categories:

- Biomass gasification
- Forestry
- Biogas

According to estimates, the overall carbon savings from the BERI project as of January 2011 is 240849.2tCO_2. The annual target achieved by the BERI project as of 2010 is 26,761 tCO_2 annually. A majority of the carbon savings comes from carbon sequestered through afforestation activities in the project area.

Whilst the above table represents the most likely scenario for carbon savings keeping in mind, the project achievements thus far, a quick look at a second scenario, with a separate set of assumptions, whereby the project is functioning at a greater potential provides different results[24].

Table 5.2: Total Carbon Abatement from BERI during the period 2001-2010 (Scenario 2)

Reduction from / Main components	**Total CO2 emissions sequestered (tCO_2)**
Biomass Gasification	374.74
Forestry	239222.3
Biogas	2838.2
Total	**242435.2**

In this scenario, carbon savings from biomass and biogas are higher than in the scenario 1[25]. The total carbon savings from the BERI project in this scenario is 242435.2 tCO_2. The

[24] For specific assumptions on this scenario, see the relevant sections

[25] No separate scenario was run for afforestation activities.

annual target achieved by the BERI project as of 2010 is 26,937 tCO_2 annually. A majority of the carbon savings comes from carbon sequestered through afforestation activities in the project area.

6. CONCLUSIONS

The BERI project has two immediate objectives, namely; (a) To provide a decentralised bioenergy technology package; (b) To remove barriers to large-scale adoption and commercialisation of this bioenergy technology package; the overall objective is to reduce CO_2 emissions through the promotion of bio-energy as a valuable and sustainable option to meet the rural energy services in India.

The following are the key activities undertaken by the BERI project, and the below are used as indicators to determine the overall mitigation benefits of the project till date.

- Biomass power generation
- Afforestation and Reforestation
- Biogas use

The above report established that the BERI project currently mitigates 26,761 tCO_2 annually. This can be compared to the projected target emission reduction indicated in the project document (March 2001), which projects the mitigation potential of the project to be in the range of 71,000 tCO_2 annually. A second possible scenario indicates only a slightly higher rate of carbon savings from biomass power and biogas, estimated to be 26,937 tCO_2.

As illustrated, the contribution of the afforestation and reforestation efforts contributes the maximum amount to the carbon mitigation. The 2,933 ha of forest and farm land afforested is responsible for more than 90% of the total carbon savings from the BERI project, thus dwarfing contributions from the biomass power and biogas units installed. Taking carbon sequestration out of the equation will indicate annual savings of 180.7 tCO_2.

It is however expected the biomass gasifiers and biogas units will be functioning at full technical potential by the time the project draws to a close in 2012. This will sufficiently increase the carbon emissions saved from biomass power and biogas in the project area.

The activities arising as a result of the project have thus led to a positive impact on the environment. It is inevitable that the carbon mitigation potential of the BERI project is much higher than is currently indicated. If all the indicators are working at their full technical potential and the local community is given full support, the carbon mitigation benefits of the projects will be significantly higher.

The importance of monitoring annual CO_2 benefits must also be highlighted as this provides an incentive to sustain use of the biogas units and power plants. Furthermore, is becomes crucial to set targets for the beginning and end of each year so as to promote sustainable use of resources.

ANNEXURE

Annex 1: Total biomass power generated

1) **Capacity:- 500 KW**

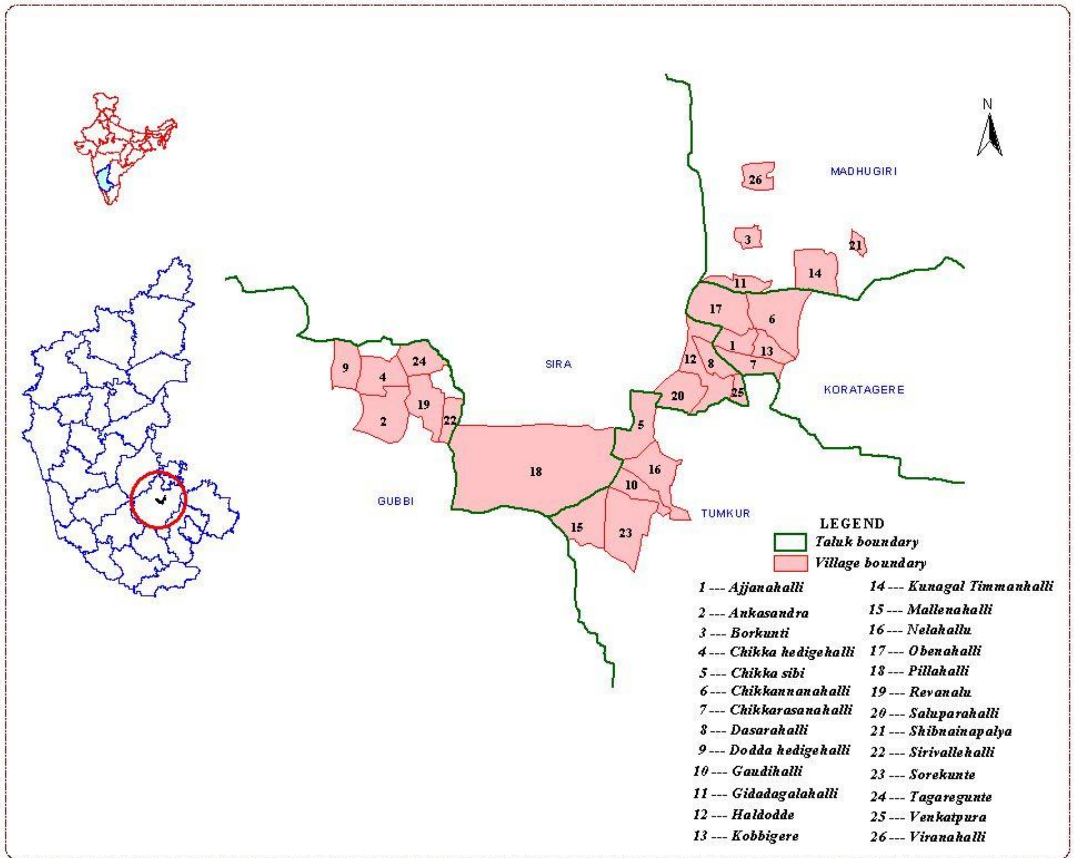
i) 200 KW (gas engine) - DG-1
ii)100 KW (gas engine) - DG-2
iii) 100 KW (gas engine) - DG-3
iv)100 KW (dual mode) - DG-4 (Kept Idle)

2) **Date of commissioning :- 24-01-2007**

3) **Generation Details Month Wise**

Year	Month	DG-1 KWH	No.of Days working	DG-2 KWH	No.of Days working	DG-3 KWH	No.of Days working	Total Generation KWH	Total No.of working days	Export KWH
2007	Jun-07	1325	6	3976	9	2805	8	8121	23	-
	Jul-07	4737	10	5456	10	15	1	10228	21	-
	Aug-07	293	3	3692	8	0	0	3996	11	-
	Sep-07	3842	8	1568	5	0	0	5423	13	-
	Oct-07	4582	10	794	4	455	3	5845	17	-
	Nov-07	7984	9	772	4	247	3	9016	16	-
	Dec-07	32192	15	16	3	892	4	33118	22	45288
TOTAL		54955	61	16274	43	4414	19	75747	123	45288
2008	Jan-08	3260	4	0	0	2750	11	6014	15	3824
	Feb-08	3179	2	16566	8	3160	7	22915	17	14256
	Mar-08	26976	13	1713	4	2046	6	30752	23	19632
	Apr-08	13681	7	0	0	2680	10	16368	17	10376
	May-08	8144	5	261	1	4963	10	13374	16	8560
	Jun-08	7482	6	0	0	5592	8	13080	14	7688
	Jul-08	8658	10	0	0	5382	12	14050	22	11504
	Aug-08	263	1	0	0	2739	6	3003	7	1816
	Sep-08	0	0	0	0	0	0	0	0	0
	Oct-08	0	0	486	2	1887	4	2375	6	1528
	Nov-08	1543	3	0	0	4668	10	6214	13	3656
	Dec-08	6813	6	1712	4	1299	3	9834	13	5352
TOTAL		79999	57	20738	19	37166	87	137979	163	88192
2009	Jan-09	4907	9	2034	8	4644	17	11602	34	6792
	Feb-09	0	0	0	0	1164	6	1164	6	560
	Mar-09	0	0	0	0	0	0	0	0	0
	Apr-09	0	0	0	0	0	0	0	0	0
	May-09	0	0	0	0	0	0	0	0	0
	Jun-09	0	0	0	0	0	0	0	0	0
	Jul-09	0	0	0	0	0	0	0	0	0
	Aug-09	0	0	0	0	0	0	0	0	0
	Sep-09	0	0	0	0	326	1	326	1	216
	Oct-09	0	0	0	0	509	3	509	3	576
	Nov-09	0	0	0	0	32618	23	32618	23	23648
	Dec-09	0	0	0	0	6807	6	6807	6	4960
TOTAL		4907	9	2034	8	46068	56	53026	73	36752
2010	Jan-10	0	0	0	0	377	2	377	2	272
	Feb-10	0	0	0	0	0	0	0	0	0
	Mar-10	0	0	0	0	0	0	0	0	0
	Apr-10	0	0	0	0	0	0	0	0	0
	May-10	0	0	0	0	12497	14	12497	14	8744
	Jun-10	0	0	0	0	56054	30	56054	30	39048
	Jul-10	0	0	0	0	23463	17	23463	17	16840
TOTAL		0	0	0	0	92391	63	92391	63	64904
GRAND TOTAL		139861	127	39046	70	180039	225	358946	422	235136

Annex 2: Project Boundary



Annex 3 (a): Project location of energy forest model on Forest Department lands under BERI project in Tumkur district

Location	Survey Number	Area (ha)
	Gubbi Range	
Nayakanahalli	10	36.23
Thogarikunte	18,19,24	28.05
Siruvallehalli	9,20,21,22	15.72
Nayakanahalli(Mallenahalli)	11	20.00
Nayakanahalli(Mallenahalli)	21,22	15.00
Nayakanahalli(Mallenahalli)	19,20	20.00
Nayakanahalli(Mallenahalli)	22	20.00
Nayakanahalli(Mallenahalli)	22	10.00
Thogarikunte		15.00
Ankasandra		50.00
Bodathimmanahalli (Ankasandra)	8,9,10	25.00
Bodathimmanahalli (Ankasandra)	8,9,11	15.00
Bodathimmanahalli (Ankasandra)	8,9,12	25.00
Bodathimmanahalli (Ankasandra)	8,9,13	25.00
Dasappanahalli (Ankasandra)	35	50.00
Dasappanahalli (Ankasandra)	34	35.00
	Koratagere Range	
Chikkannanahalli	7,8,9&14	7.00
Obenahalli	22,23,24,25	24.00
Kabbigere		6.00
Kurihalli		50.00

Thovinakere		19.00
Devarahalli		25.00
Devarahalli		10.00
	Madhugiri Range	
Gidadagalahalli	19	12.50
A.M.Kaval-Boragunte		30.00
A.M.Kaval-Veerannanahalli-Block-I		30.00
A.M.Kaval-Veerannanahalli-Block-II		30.00
A.M.Kaval-Kunigal Thimmanahalli Block-III		30.00
A.M.Kava-Gidadagalahalli-Block-IV		30.00
A.M.Kaval		30.00
Badavanahalli SF (Gidadagalahalli VFC)		40.00
Badavanahalli SF (Boregunte VFC)		40.00
A M Kaval		15.00
Madenahalli		30.00
Madenahalli		30.00
Muddappanapalya		15.00
Goddanapalya	14	10.00
	Sira Range	
Haldodderi	70,71,72	20.00
B.Ranganahalli		25.00
Saluparahalli		20.00
Thippanahalli	9,20, 21,22, 23,24	30.00
Thippanahalli	28,29, 31, 32, 33, 34, 35, 36, 37, 38	30.00
Seebi	181, 182,183	30.00
Seebi	184,187, 188, 189, 190, 191, 192, 193, 194	30.00

Seebi	31, 32, 33, 38, 39, 40	20.00
Seebi		10.00
Huchabasavanahalli	10,20,23	25.00
Huchabasavanahalli	28,23,30	25.00
Huchabasavanahalli	28,23,31	9.00
Dodderi block I & II		23.00
		1215.50

Annex 3 (b): Project location of Assisted Natural Regeneration on Forest Department lands under BERI project in Tumkur district

Location	Survey Number	Area (ha)
	Korategere Range	
Chikkannanahalli	7,8,9&14	23.00
Obenahalli	22,23,24,25	109.00
Devarahalli		5.00
	Madhugiri Range	
Gidadagalahalli	19	10.50
A.M.Kaval-Veerannanahalli-Block-I		50.00
A.M.Kaval-Veerannanahalli-Block-II		50.00
A.M.Kava-Gidadagalahalli-Block-III		50.00
A.M.Kaval-Kunigal Thimmanahalli Block-IV		40.00
A M Kaval		25.00
A M Kaval		25.00
Madenahalli		30.00
Madenahalli		30.00
Muddappanapalya		30.00

Muddappanapalya		30.00
Muddappanapalya		30.00
	Sira Range	
Saluparahalli		20.00
B.Ranganahalli		40.00
Saluparahalli		7.00
Chikkaseebi		50.00
Chikkaseebi		40.00
Haldodderi	70,71	50.00
		744.50

Annexure 3 (c): Project location of roadside on Forest Department lands under BERI project in Tumkur district

Location	Survey Number	Area (ha)
	Gubbi Range	
Sathenahalli		1.00
Talakoppa To Sheshanahali Road		4.00
	Koratagere Range	
Surenahalli-Kabbigere Road		4.00
kabbigere-Obenahalli Road		3.00
Ajjenahalli-Gidadagalahalli		3.00
Kestur to chikkannanahalli road		6.00
	Madhugiri Range	
Gobalagunte Road		3.50
Dandinadibba Road		6.00
Badavanahalli to Talaguda road		6.00

Ajjenahalli-Badavanahalli	9.00
Sira Range	
NH4-Jogihalli	6.00
N.H.4 to Haldodderi	6.50
S.Sagara to Badarahalli	6.00
Byadarahalli to Kallgudi road	3.00
Channenahalli to Kabbigere Road	3.00
Tumkur Range	
NH4-Mllenahalli	3.00
Gollahalli & Namadachilume	4.00
	77.00

Annexure 3(d): Project location of Clonal Eucalyptus on Forest Department lands under BERI project in Tumkur district

Location	Survey Number	Area (ha)
	Koratagere Range	
Siddarabetta		1.00
	Sira Range	
Melkunte		2.00
Melkunte Nursery		5.00
		8.00

Annex 4(a): species specific equations of trees

Species	Volume/Biomass equation	R^2	Reference
Acacia auriculiformis	$V=0.287691-2.825587*D+0.054761DH$ $+22.264775D^2-(0.004788/D$	0.9924	FSI, 1996
Albizia amara	$\sqrt{V}=-0.07109+2.99732D-0.26953\sqrt{D}^2$	0.965	FSI, 1996
Anogeissus latifolia	V=0.289-2.651 D+22.772D^2	NA	FSI, 1994
Azadirchta indica	$AGB=19.2224+238.5245D^2H$	NA	FSI, 1996
Buchnania sp.	$V=0.00508+0.3582D^2H$	0.915	FSI, 1996
Cassia fistula	$V=0.066+0.287D^2H$	0.965	FSI, 1996
Cassia siamea	$V=0.05159-0.53331D+3.46016D^2+10.18473D^3$	0.993	FSI, 1996
Dalbergia latifolia	$V=0.28945-2.46225D+20.54462 D^2$	NA	FSI, 1996
Dalbergia paniculata	$\sqrt{V}=0.76896+7.31777D-4.01953\sqrt{D}$	0.91580	FSI, 1996
Dalbergia sisso	$V=-0.013703+3.943499 D^2$	NA	FSI, 1996
Diospyros melanoxylon	$V=0.01456+0.32613D^2H$	0.920	FSI, 1996
Diospyros sp.,	$V=0.92625+7.86461D-4.67223\sqrt{D}$	NA	FSI, 1996
Emblica officianalis	$V=0.01244+0.3422 DH$	0.8312	FSI, 1996
Eucalyptus sp.,	$V=0.02894-(0.89284D)+(8.72416D^2)$	0.989	FSI, 1996
Ficus bengalensis	$\sqrt{V}=0.03629+3.95389D-0.84421\sqrt{D}$	0.981	FSI, 1996
Ficus sp.,	$\sqrt{V}=0.03629+3.95389 D-0.84421 \sqrt{D}$	0.9812	FSI, 1996
Lagerstroemia parviflora	$V=0.11740-1.58941D+ 9.76464 D^2$	0.9697	FSI, 1996
Lannea coromandelica	$V= 0.093318-1.531417 D+9.01159 D^2$	0.5750	FSI, 1996
Pterocarpus marsupium	$V=0.70-2.295D+9.429D^2$	NA	FSI, 1996
Syzygium cumini	$V=-0.002043+0.361337D^2H$	0.97	FSI, 1996
Tectona grandis	$V=0.086+5.641D^2$	NA	FSI, 1996
Terminalia alata	$V=0.06517-0.21738D+3.96894 D^2 +4.63954D^3$	NA	FSI, 1996
Terminalia bellerica	$V=0.26454-3.05249D+12.35740 D^2$	0.9692	FSI, 1996

Terminalia paniculata	$V=0.131-1.87132\ D+9.47861\ D^2$	NA	FSI, 1996
Writtia tinctoria	$\sqrt{V}=0.23229+4.41646D-1.5598\sqrt{D}$	0.96970	FSI, 1996
General Equation	$V = 0.058 + 4.598D^2$	NA	FSI, 1996
Thespesia populanea	$AGB=119.1276+101.0613D^2H$	NA	FSI, 1996

B=Biomass; V= Volume; D = DBH; H=Height

Annex 4 (b) Specific values of Wood density applied to following species

Species	Wood density	Species	Wood density
Acacia auriculiformis	0.5 to 0.65	Ficus bengalensis	0.48
Acacia mangium	0.45 to 0.69	Ficus recimosa	0.48
Acacia nilotica	0.83	Ficus religiosa	0.67
Acrus zapota	0.67	Ficus sp.,	0.39
Albbizia lebbek	0.66	Glyricidia maculata	0.67
Artocarpus hirsutus	0.6	Grevillea robusta	0.62
Azadirachta indica	0.69	Lagerstroemia parviflora	0.62
Bauhinia purpuria	0.67	Leucaena leucocephala.	0.64
Bauhinia sp.,	0.67	Mangifera indica	0.52
Bauhinia variegata	0.67 to 0.82	Murraya koenigii	0.67
Butea manosperma	0.48	Pongamia pinnata	0.67
Cassia fistula(Batae)	0.71	Pterocarpus marsupium	0.67
Cassia siamea	0.67	Sema ruba glaca	0.67
Casurina equisetifolia	0.83	Syzigium cumini	0.74
Dalbergia latifolia	0.85	Tamarindus indica	0.75
Dalbergia sisso	0.77	Tectona grandis	0.7
Delonix regia	0.67	Terminalia alata	0.87
Diospyros sp.,	0.7	Terminalia arjuna	0.68

Emblica officinalis	0.8	Terminalia paniculata	0.80
Eucalyptus sp.,	0.89		

Annex 5: Biogas Survey Results

Taluk	Village	HH's served	Existing Usage	Previous usage	Qty of wood used without BG units (kg/day)	Qty of wood used with BG units (kg/day)
Gubbi						
	Chikkahedagenahalli	3	–	–	5	0
	Chikkahedagenahalli	3	–	–	10	0
	Ankasandra	3	–	✓	LPG	none
	Ankasandra	3	–	✓	10	4
	Doddaheginahalli	4	–	–	10	0
	Doddaheginahalli	3	–	✓	5	0
	Doddaheginahalli	3	–	✓	10	6
Tumkur						
	Malenahalli	3	✓	✓	20	10
	Malenahalli	3	✓	✓	1	3
	Malenahalli	3	✓	✓	10	5
	Chikkasebi	3	–	✓	15	10
	Chikkasebi	3	–	✓	16	10
	Chikkasebi	3	✓	✓	5	4
	Sorakunte	3	–	✓	5	3
	Sorakunte	3	✓	✓	8	0
	Soregunte	3	✓	✓		
	Sorakunte	3	–	✓	8	1
	Sorakunte	3	–	✓	6	3
	B.G Halli	3	–	✓	8	0
	B.G Halli	3	–	–	0	0
Sira						
	Salaparahalli	3	–	✓	20	13
	Venkatapura	1	✓	✓	12	8
	Venkatapura	4	–	✓	12	10
	Hunjanal	3	–	✓	8	3
	Haladodderi	3	–	✓	5	2
	Dasarahalli	3	–	✓	10	8
	Dasarahalli	3	–	✓	5	0
	Dasarahalli	3	–	✓	5	3
Koratgere						
	Chikkanahalli	3	–	✓	6	4
	Chikkanahalli	5	–	✓	5	3
	Chikkanahalli	3	–	✓	7	5.5
	Kabbigere	10	–	✓	3.5	3
	Kabbigere	5	–	✓	5	2
	Chikkarasarahalli	3	–	✓	8	3
	Obenahalli	3	–	✓	5	3
	Kabbigere	3	–	✓	5	2
	Ajanahalli	3	–	✓	10	5
	Kabbigere	3	–	✓	5	3
	Obenahalli	3	–	✓	5	2
	Kabbigere	5	–	✓	15	0
	Veeranahalli	3	–	✓	6	2
Madhugiri						
	Boregunte	3	–	✓	5	3
	Boregunte	3	✓	✓	7	4
	K.T.halli	3	–	✓	8	0
	K.T.halli	3	✓	✓	6	2
	K.T.halli	3	–	✓	6	3
	K.T.halli	4	–	✓	10	2
	Seebinayanapalya	2	✓	✓	6	3
	Seebinayanapalya	2	–	✓	7	4
	Seebinayanapalya	3	–	✓	6	3
	Giddadahalli	3	–	✓	10	6
	Giddadahalli	3	–	✓	6	3
	Sarigepalya	3	–	✓	5	2
	Total	**171**			**7.8**	**3.5**

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