SAHYOG Project Grant Agreement no: 289615

Deliverable report

D2.1: Biomass and Biowaste Inventories Report

February 2013

Responsible Beneficiary: ENEA/TERI

Project Co-ordinator: ENEA

Authors:

Neeta Sharma, Silvia Tabacchioni, Luigi Chiarini - ENEA

Priyangshu M Sarma – TERI

Project co-funded by the European Commission within the 7th Framework Programme		
Dissemination level		
PU	Public	**x**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential only for members of the consortium (including the Commission Services)	

TABLE OF CONTENTS

This report comprises the “Biomass and Biowaste inventory” which is accomplished under task 2.1 of the project SAHYOG “Strengthening networking on biomAss researcH and biowaste conversion – biotechnologY for EurOpe India integration” co-funded under the European Union 7th Framework Programme.

Introduction

The rapidly growing energy demand is becoming a challenge for human development because of fast depleting energy resources, effects on the environment and national energy security. These challenges have lead to consider the use of biomass resources and other organic waste materials as alternative sources for food/feed, chemicals, energy and materials, possible solutions for major societal challenges. The Energy Strategy 2020 of the European Commission calls for increased use of renewable resources in the energy system, expecting the use of biomass to account for up to 56% of the renewable energy supply in the EU27 by 2020.

On the basis of research being carried out to investigate and demonstrate the potential of biomass and bio-waste in Europe and in India, some technical, economic and financial information has become available in recent years; however, up-to-date information on biomass and biowaste is still partially lacking for users.

The main objective of the Task 2.1 on Biomass and Bio-wastes inventories is to collect the most up-to-date data on biomass production and availability from three major sectors: forestry, agriculture and wastes in Europe and India.

Analysis for availability of the potential biomass and bio-waste feedstock for sustainable conversion to bio-material and bio-energy was performed at state level through an intensive consultation of existing databases and reports in Europe and India.

The layout of the present database was developed through consultation with all the European and Indian project members and Stakeholders invited at the 1st Stakeholders Meeting held in Bruges (Belgium) in May 2012.

The result of the inventories will represent the basis to develop a joint EU-India Strategic Research Agenda (SRA), as foreseen within the framework of SAHYOG project.

The availability of biomass and bio-waste resources in EU and India will be monitored throughout the duration of the project and the inventory will be updated accordingly.

SECTION I

1. Biomass Inventories – Europe

1.1 Sources of information

A number of sources of information available both in Europe and in India were consulted to compile the final SAHYOG Inventory. A brief description of the reports that were consulted to finalize SAHYOG database is given below.

1.1.1 National Renewable Energy Action Plans (NREAPs)

The database of NREAPs was provided from each Member State in response to the Article 4 of the renewable energy Directive (2009/28/EC). Each Member State was requested to complete a template published by the Commission to explain how it will reach 2020 targets. These reports, available for download at the website www.buildup.eu, contain data on domestic supply, imports, exports and primary energy production of the main biomass categories: forestry, agriculture and fishery, and wastes.

The first report contains data that refer to years 2006-2007, while the successive progress report that refers to years 2009-2010, contains the data updated only for some biomass categories.

1.1.2 Statistical Report published by European Biomass Association (AEBIOM)

AEBIOM statistical reports are annually published by European Biomass Association, a non-profit Brussels based international organization whose mission is to represent interests of bioenergy stakeholders at EU level. These reports provide a comprehensive collection of data on the contribution of biomass to the energy system in the EU27 and are compiled from data published in many different EU sources other than the information gathered from AEBIOM members.

Basic information provided therein is about biomass resources originating from forest, agricultural and waste streams. It also contains the information about the end use of biomass: electricity, heat and transport. The most recent reports published in years 2011 and 2012 were consulted for the SAHYOG inventories.

1.1.3 EUBIONET III project reports

The EUBIONET III project (Solutions for biomass fuel market barriers and raw material availability - IEE/07/777/SI2.499477, www.eubionet.net) was funded by the European Union's Intelligent Energy Programme over the period 2008-2011. The Member State partners of the project were: Denmark, Slovakia, Latvia, Germany, Sweden, Belgium, Czech, Norway, Austria, Greece, Netherlands, Italy, Lithuania, UK, Portugal, Slovenia, Spain and Finland.

These reports provide data for each country partner on the biomass from forest, plantation and other virgin wood, by-products and residues from wood processing industry, herbaceous and fruit biomass resources as well as on the current use of biomass for energy use.

Most of data refer to the year 2006; only very little data refer to the years 2007, 2008 and 2009.

1.1.4 BIOMASS FUTURES project (Biomass role in achieving Climate Change & Renewable EU policy targets, funded by the EU Intelligent Energy Program).

In this report most of the data is described in the following four main categories:

- Biomass from Agricultural land and by products: dedicated Energy Crops (specifically cultivated crops e.g. Miscanthus, Switch grass, Reed Canary grass, Poplar, Willow, Rapeseed, Maize etc.) and agricultural by products;
- Biomass from Forestry: forestry biomass and forestry residues
- Biomass from waste sector;
- Others: Paper & paper mills, contribution of peat to the EU Energy System.

The methodology for this comparison of biomass resource assessment studies has been based on the results of the BEE project (BEE website: www.eu-bee.info).

This project mainly reviews the biomass assessments in Europe at country level and explains that a share of the differences between studies can be described by an appropriate categorization of studies according to method, biomass type and potential types. Remaining discrepancies can be assessed by comparing individual studies only but not in a systematic manner due to lack of information provided by authors and individuality of assumptions.

Moreover, among the most obvious reasons for large differences between estimates of the biomass resource assessments reviewed by the BEE project (BEE 2008) is the conceptual potential type that is addressed.

1.1.5 Others

Additional sources have been used only for the following three countries:

- **Greece**
  - RENEW (Renewable Fuels for Advanced Power trains) Project, Deliverable D5.1.1, www.Renew-fuel.com
  - Small Scale Biomass and Solar Technologies (ACCESS) Project
  - Hyvolution Project, FP6 Integrated Project
  - EU, IEE Project, BIG EAST, Biogas Potential in Greece, Summary Report, Deliverable 2.2

- Boukis et al, Renewable and Sustainable Energy Reviews, 13 (2009), 971-985
- Zafiris C., European Biogas Workshop, Biogas in Greece, Current Situation and Perspectives, June 2007
- http://www.eurobserv-er.org/downloads.asp

- **Italy**
  - ISTAT / EUROSTAT

- **Spain**
  - Gomez et al., 2010 A estimation of the energy potential of agro-industrial residues in Spain. Resources, Conservation and Recycling 54: 972–984

- **The United Kingdom**
  - Digest of UK energy statistics' (DUKES) (https://www.gov.uk)

1.2 Categorization and Database Structure

Biomass categories used in the SAHYOG database were mainly the same as reported in the NREAPs database. However, some modifications have been done concerning mainly the subcategories. For each main category and subcategory, biomass supply for energy, materials and chemicals have been reported.

1.2.1 Biomass from Forestry

This section is further divided into two categories: Direct supply of wood biomass from forests and other wooded land for energy, materials and chemicals production, and Indirect supply of wood biomass for energy, materials and chemicals production.

1.2.2 Biomass from Agriculture and Fishery

This section is further divided into two categories: Agricultural crops and fishery products directly provided for energy, materials and chemical production and Agricultural by-products / processed residues and fishery by-products for energy, materials and chemicals production. In the first category, the additional information provided was as follows: the different arable crops were reported separately to gain more insight. In the second category, the two more subcategories added were waste oils and crop residues.

1.2.3 Biomass from Waste

In this section, the same categories and subcategories as in NREAP were maintained. However, these were rearranged into four categories: Biowaste, Biodegradable fraction of industrial wastes, Sewage sludge and Landfill gas.

The SAHYOG database provides the following information for each biomass resource category:

1. Total available biomass (it corresponds to the technological biomass potential, ie. the fraction of the theoretical potential which is available under the regarded techno-structural framework conditions with the current technological possibilities such as harvesting techniques, infrastructure and accessibility, processing techniques (Chum *et al*., 2011: Bioenergy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA)
2. Used biomass (biomass utilized for energy, chemical, and material production)
3. Net biomass potential (total available biomass – used biomass)
4. Energy content of total available biomass
5. Conversion processes (processes used for biomass transformation)
6. Geographical location (main geographical locations where biomass was produced/collected)
7. Source/link (data source)
8. Reference year (year of biomass production/collection)
9. Notes (additional information)

Database has been set up using MS Excel program.

As agreed with all partners, data in the database refer to the domestic availability of biomass and biowastes, that can be used for the production of energy, materials and chemicals etc.
Most recent data referring to the years 2006-2009 were presented in this report. However, in some of the cases, data referring to the year 2010 were also presented.

For all countries, import and export data were not taken into account.
The energy content of each biomass category was calculated by using the low heating value of a specific biomass (LHV expressed in MJ/Kg) reported in Phyllis database (www.ecn.nl/phyllis/). The calculations were made by multiplying the LHV with the total amount of biomass (DW). The energy content was expressed un terajoule (TJ) or kilotons oil equivalents (k toe).

Some additional information for the interpretation of the database is given below:

1. The surface area (hectares) dedicated to energy crop cultivation, when possible, is reported in the column “Notes” of the database.
2. Dry weight biomass value has been reported, unless specified.

1.3 Results

Based on all the possible available information reported in the existing databases and reports in Europe and India, at the regional and local level, the set up of a comprehensive SAHYOG biomass inventory was accomplished.

Nevertheless the wealth of information was provided by the single sources, many shortcomings and gaps were found while collecting the biomass data. Main problems encountered during data collection are listed below:

1. There is a lack of consensus among the different consulted databases as far as the meaning and use of different biomass and bio-waste potentials is concerned.

2. It is not always clear which type of biomass potential is used for the single biomass categories. Apparently, in some cases, availability of different biomasses has been calculated taking into account different types of biomass potential.

3. Measure units are not homogenous throughout the databases.

4. All datasets and reports consulted for SAHYOG inventories show incomplete data.

5. A lot of discrepancies in the available data and only few estimates exist regarding the biomass database in India as compared to Europe.

In order to ensure as high accuracy as possible in our inventory, all the data included in the above-mentioned databases have been screened carefully and, whenever possible and/or necessary, biomass availability using first-hand data from national statistical databases was calculated.

One of the example of above-mentioned problems, represents the case of straw. It represents a very important source of biomass; in most publicly available databases, straw data refer to its theoretical potential, although this is not always openly stated. As data in the present database refer mostly to the technological biomass potential, no data concerning straw availability are presented, except in the case of Italy, where its technological potential was calculated based on data directly derived from the National Statistical Agency (ISTAT).

An evaluation of the data collection for SAHYOG inventories demonstrates that only 40% of 27 EU Member State inventories are complete as far as total available aggregate data (tons/m^3) is concerned. Furthermore, as can be seen in Fig. 1, all the data under the biomass resource category “Forestry” is complete, whereas in case of “Agriculture and Biowaste”, only around 50% data is found to be completed in case of EU countries, as far as total aggregate data are concerned.

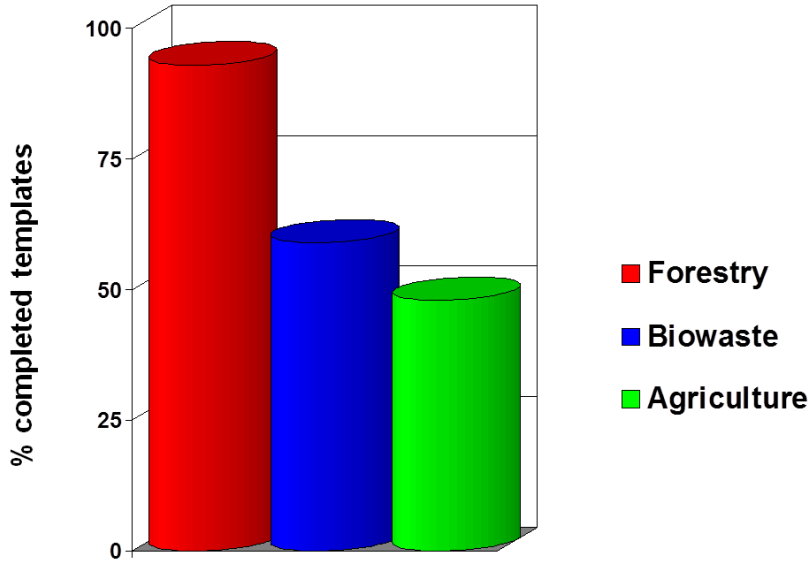


Fig. 1 Percentage of EU countries with complete aggregate data in the three main biomass categories of the database.

Most available biomass for energy, chemicals and materials in Europe is supplied from forestry. This is clearly represented in Fig 2, where the available data in terms of k toe are summarized for all the EU Member States. As already mentioned previously, in this figure and annexed database, the term availability means technological biomass potential.

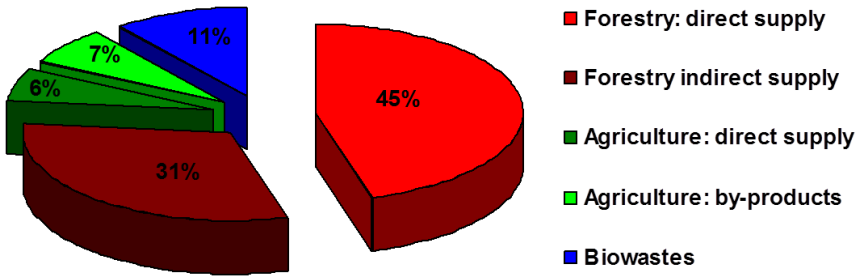


Fig. 2 Availability of different types of biomass in Europe (k toe)

The SAHYOG biomass inventory contains very little information on the really “used biomass” and its “conversion processes” as well as “net biomass information” which is strictly related to the “used biomass”. This is because of the fact that in most of the public databases, information concerning these items is missing. Recently, a report containing information on use of biomass for chemicals and materials in Germany, referring to the year 2008, was published by the Nova-Institute GmbH (Germany). However, it was not possible to use the information because biomass categories mentioned, were different from the ones adopted in SAHYOG database. Moreover, biomass import values were also included therein.

Even for the technological potential of crop residues it is difficult to get reliable figures. These residues are produced in high quantities and could be used in great amount for energy production. Some preliminary calculations have been done for Italy based on the data reported in the National Statistical Service (ISTAT/EUROSTAT). The Italian Association of Agricultural Engineering (A.I.I.A) has developed a methodology that has been used to assess total available residues (straw, crop residues and residue from clipping and extirpation of fruit trees), as shown in Fig.3. This assessment includes main Italian crops that account for a large part (about 87%) of arable land and potentially produce residues suitable for combustion (Table 1). As far as annual herbaceous crops are concerned some coarse grain crops (e.g. rye), legumes (fava bean, pea, chickpea, lentils, soy) and all horticultural products are not included. The main reasons for this exclusion are:

- these crops are not relevant in terms of cultivated surface areas or are localized in small areas
- some residues are not significant. (e.g. Lentils)
- some residues are not easy to harvest and they are chopped traditionally during harvesting
- horticultural residues are humid and they could be used for compost and/or anaerobic digestion.

As far as permanent crops are concerned about 98 % of total woody crops are included. Residues from the crops such as fig, walnut, medlar, pistachio, grapefruit, citron and small shrubs that are cultivated in some Italian regions and are not very significant have been excluded (table 1).

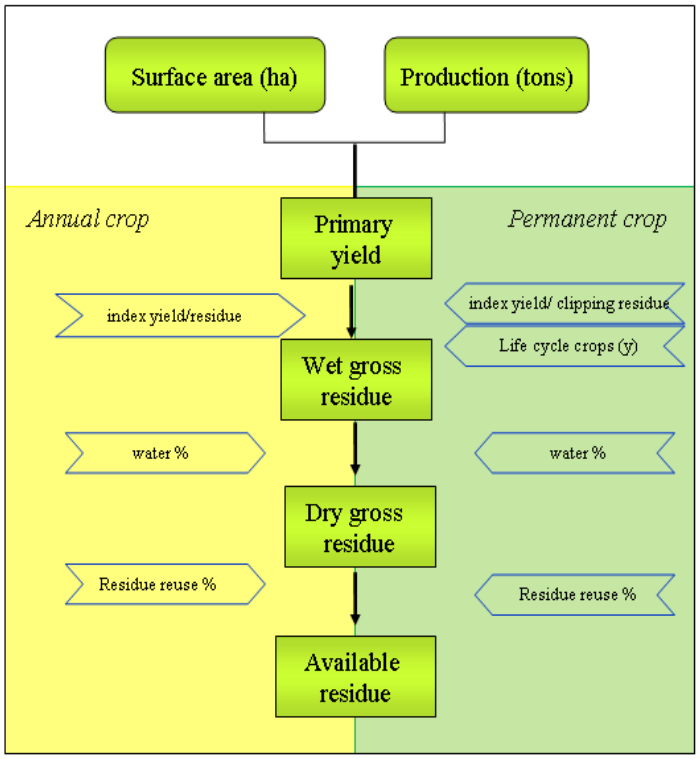


Fig.3. Schematic representation of A.I.I.A. methodology for biomass residue assessment

Selected crops		Surface area (ha)
Cereals		**3.421.437**
	Wheat	572.450
	Durum wheat	1.257.074
	Barley	273.520
	Oat	114.191
	Rice	238.459
	Grain corn	925.017
	Sorghum	40.726
Industrial crops		**120.705**
	Rapeseed	20.193
	Sunflower	100.512
Total		**3.542.142**
Fruits tree		**399.791**
	Apple	54.470
	Pear	36.876
	Apricot	18.549
	Cherry	30.067
	Peach	55.959
	Nectarine	26.663
	Plum	12.768
	Nuts	55.904
	Almond	86.184
	Kiwi	22.351
Citrus species		**163.237**
	Orange	101.245
	Tangerine	8.884
	Clementin	28.496
	Lemon	24.612
Grapes		**718.107**
vite	**Table grape**	65.511
	Wine grape	652.596
Olive trees		**1.166.839**
Total		**2.447.974**
Total crops surface area		**5.990.116**

Table 1. Agricultural Residues Evaluation of Annual & Permanent Crops in Italy (2010)

SECTION 2

2. Biomass Inventories – India

The present report focuses on the deliverable WP2 (Inventorisation of Biomass and Biowaste sources) from the coordinating countries for biomass, its availability for use/consumption and the surplus availability for energy production. To achieve this objective, the study for India has been carried out in two approaches based on the availabily of the existing data sources. Initially based on the existing data source for the entire country, an inventory on pan India basis was developed. Futher based on the availability of few data sources that categorised the information from varous Indian states, an attempt was made to prepare an inventory for 23 states. However, considering the availability of complete information for the inventory, this report will focus on the information souced through the pan India data sources.

2.1 Sources of Information

One of the major limitations for developing the Indian inventory was the non-availability of central databases for biomass resources in India. The information was available in various formats and focused mostly on the production and yield of various agricultural and plant product. The information required to meet the objectives of the project where the focus on availability of surplus biomass or bio-waste for its valorisation was not available in any central database. Information available was limited to academic reports and publications but it was specific to the objective of the study or limited to local or regional levels. Considering these limitations, the inventory had to be prepared by considering certain extrapolations on the available data from the sources mentioned below.

2.1.1 Sources for Biomass from Forestry

Even after an exhaustive data search, information on biomass availability and its source from forestry did not yield to any significant outcome. It was apparent from survey of the sources mentioned below, as all as discussion with various stakeholders, that in India forest and forest products is very difficult to be considered as a resource for any biomass conversion applications. Thus the biomass inventory prepared for India availability details from forest biomass is missing and not considered.

1. Biomass Resource Atlas of India, Indian Institute of Science, India 2004
2. Annual report of Indian States of Forest 2011
3. Annual report and publications from several state and central forest research Institute

2.1.2 Sources for Biomass from Agriculture and Fishery

Though there were no direct data source to ascertain the availability of biomass and bio-waste in India that can be utilised for valorisation through various biotechnological interventions, information on total production or yield was available in different sources. Thus for developing the inventory, the primary source of information on production and yield was taken from the following major source. This primary source information was then subjected to extrapolation as per the methods described below for deriving the available biomass and bio-waste in the country.

1. Statistical Year Book, Government of India, 2012
2. Directorate of Economics and Statistics, Government of India (http://eands.dacnet.nic.in) , 2012
3. Reserve Bank of India, Data base, Ministry of Agriculture, Government of India , 2012
4. TIFAC Biomass resources Report (Technology Information, Forecasting and Assessment Council), 2009

Apart from these, there are the annual report published in India by authenticated Government sources, which clearly defining the annual production of the country for several agricultural commodities. These data sources reveal the production data for agricultural crops in most recent year 2010-2012. Few of the documents are mentioned below. The individual data sources like academic publications also have a mentioned in the Biomass inventory attached along with this report.

1. Several states Directorate of Land Record, India
2. Several states Commissioners of Agriculture, India
3. Several states Directorate of Horticulture, India
4. Several States Directorate of Economics and Statistics websites
5. Several States Directorate of Agriculture websites
6. Several States Forest Department
7. Biomass Assessment Report 2011, RRECL Rajasthan

2.1.3 Sources for Biomass from Waste

Though there was no central data base available for this category, the inventory was prepared by extrapolating the data available from the following two sources.

1. Central Pollution Control Board report (CPCB,2012)
2. Report on Sustainable Solid Waste Management in India by Ranjith Kharvel Annepu, Columbia University in the City of New York, 2012.

2.2 Limitation of Indian Biomass Inventory

It was a major challenge to document the inventory for biomass and bio-waste availability in India. There was no information available in central databases from where the initial inferences could be drawn. Further for few resources like Biomass from forestry, information was limited, as forest is conserved and legal issues for usage of forest biomass is applicable by Government of India. The information on TOF (Trees outside forest) is very limited and no recent information is present in any secondary sources available to the investigators.

Likewise, there is no record of residues from sawmilling, woodworking, furniture industry, by-products of the pulp and paper industry (black liquor, tall oil), processed wood-fuel, post-consumer recycled wood, in Indian Biomass inventory. Similarly the data for food, fruit processing and fishery biowaste is missing in Indian biomass inventory as no authenticated secondary source for these were present in India. As the information is either limited to local sources or to the small or medium scale industries under which these wastes are generated, a proper documentation through secondary data was not possible.

2.3 Categorization

Biomass categories used in the SAHYOG database in India was mainly similar as used by EU partners and divided in to three main broad categories. All these categories were already discussed above in detail.

The SAHYOG database provides the following information for each biomass resource category:

1. Total available biomass (it corresponds to the biomass potential, i.e. the fraction of the theoretical potential which is available under the regarded techno-structural framework conditions with the current technological possibilities such as harvesting techniques, infrastructure and accessibility, processing techniques
2. Used biomass (biomass utilized by farmers and others for fodder, energy and lively hood and material production)
3. Net biomass potential (Total available biomass – Used biomass)
4. Energy content of Net biomass (Surplus)
5. Conversion processes (processes used for biomass transformation)
6. Geographical location (main geographical locations where biomass was produced/collected)
7. Source/link (data source)
8. Reference year (year of biomass production/collection)
9. Notes or any additional information

Database or the inventory has been set up using MS Excel program.

2.4 Methodology

As described earlier, due to non-availability and limited information on biomass availability in the country, a set of extrapolation had to be carried out to prepare the Indian inventory. As agreed with all investigators, data in the Indian database refer to the domestic availability of biomass and bio wastes, which can be used for the production of energy, materials, and chemicals. The secondary data source considered for the inventory was collected from the time frame of 2010-2012.

From India side there was no biomass reports from forest as it is marked conserved and legal implications for usage of forest biomass is there by Government of India, while data on TOF (Trees outside forest) is very limited and no recent information is present in any secondary sources available. Whereas to assess the availability of agricultural biomass, the crop production statistics were taken into consideration since the data on consumption and waste is not reported any relevant reports. For agricultural data, the total amount of residues (actual biomass) was calculated using Crop Residue Ratio (CRR) but the data for used and surplus residues (net biomass) were not available. The reference used to calculate CRR ratio was Hiloidhari *et al.* Renewable and Sustainable Energy Reviews 15 (2011) 1885–1892 and Chauhan, Biomass and Bioenergy (2012), 205-212.

The CRR value was used for the extrapolation of the Biomass residue data using the production data from these three authenticated sources. The comparative analysis of all the three sources (Statistical Year Book, India 2012, Directorate of Economics and Statistics, Department of Agri. Coop. India) was carried out for Pan India biomass estimation (Production, Biomass residue generation, Biomass surplus, Power potential). Net biomass potential is determined by multiplying the available biomass with the residue availability factor. The value of availability factor for rice straw, husk and other remaining crop residues is taken as 50%, 75% and 80%, respectively.

Net biomass potential = Total available biomass × residue availability factor
(*Source: Hiloidhari et al. Renewable and Sustainable Energy Reviews (2011) 15: 1885–1892, and thus used biomass was calculated)*

The Energy Content was calculated as the total energy content of the biomass = Net Biomass Potential of the specific biomass × lower heating value of the biomass, (The energy content is obtained for the whole year for the specific biomass), (

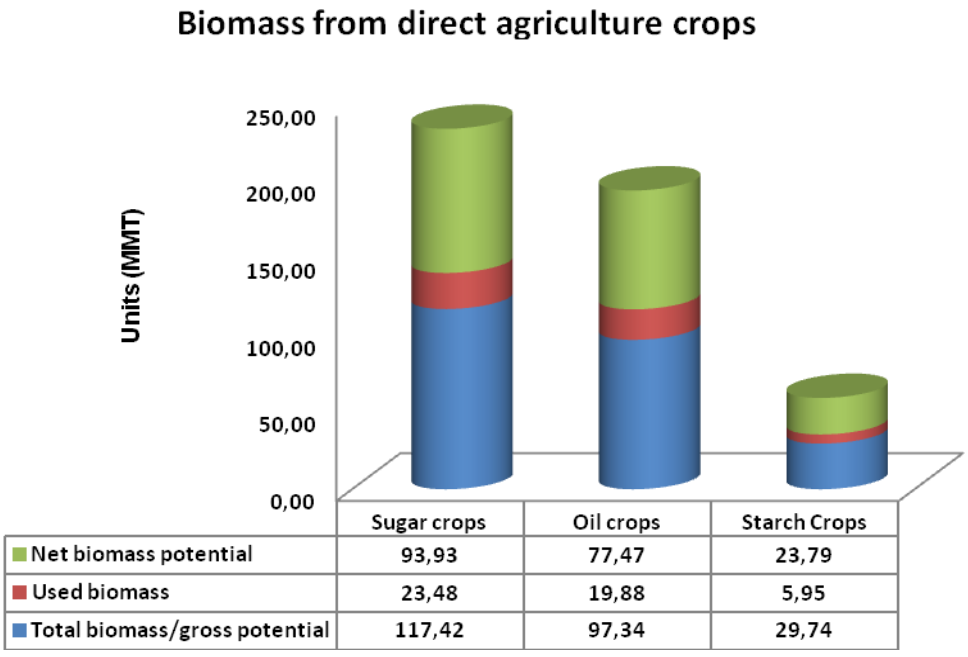
In the inventory sheet, energy content is calculated as,
Energy content (TJ/ year) = Net biomass potential (MMT) × Lower Heating Value (MJ/Kg) × 1000
Where 1000 is the factor to convert MJ to TJ.
(*Source: Hiloidhari et al. Renewable and Sustainable Energy Reviews (2011) 15: 1885–1892, and thus used biomass was calculated)*

The Pan India biodegradable fraction of municipal solid waste was calculated to be 25542726.84 TPY, as mentioned in the thesis entitled “Sustainable Solid Waste Management in India” by Ranjith Kharvel Annepu, Columbia University in the City of New York, Sponsored by the Waste-to-Energy Research and Technology Council (WTERT) and taken the reference of latest CPCB, India survey. Since the amount of MSW generated is not available, extrapolations were done on the population basis, in order to calculate the actual amount of waste generated and the power generation potential that can be derived from it. The total sludge generated was calculated as 70mg/L, based on the information provided by ETP treating sewage waste water by activated sludge process. The calorific value of dried sewage sludge is 13.8 MJ/kg. Hence, the energy content was calculated by multiplying the total sewage generated with the calorific value in the present inventory sheet. In case of municipal waste the bio-waste is not separated from hazardous waste.

2.5 Results

From first category i.e. Biomass from forest, as already mentioned in India there was no information available from authenticated sources about Biomass from forestry, therefore Indian Biomass inventory sheets were kept blank for this category and moreover data on TOF (Trees outside forest) is very limited and no recent information is present in any secondary sources available. The second and most important category from Indian side is Biomass from Agriculture and Fisheries, the majority of the biomass generated in India come from this category this could be inferred from the data collected that most of the information presented in Indian Biomass inventory is available on Agricultural crops, Oil crops, Agricultural by-products (Husk, Straw, Stover).

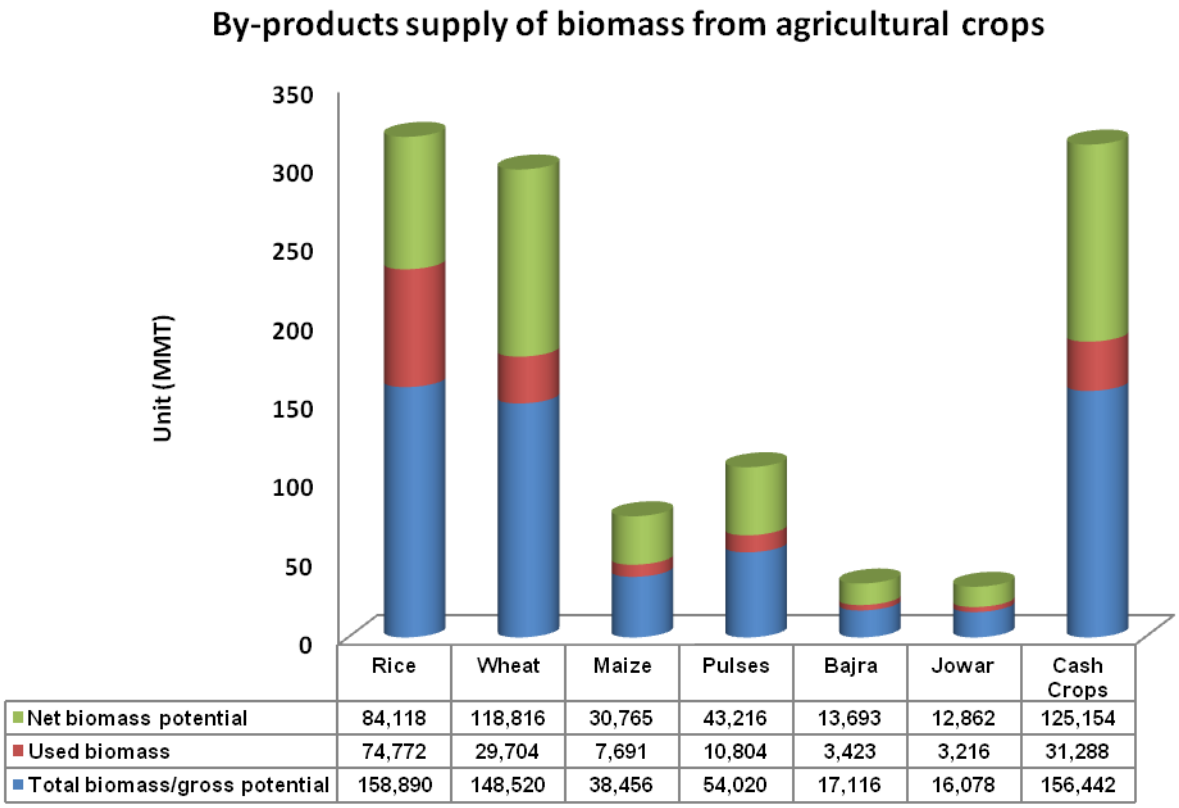
The major biomass sources which comes direct from agricultural land consist of Sugar crops (117.42 MMT) followed by Oil crops (97.3 MMT) and Starch crops (29.74 MMT) (Fig.1).



	Sugar crops	Oil crops	Starch Crops
Net biomass potential	93,93	77,47	23,79
Used biomass	23,48	19,88	5,95
Total biomass/gross potential	117,42	97,34	29,74

Fig. 1 Biomass from direct agriculture crops

The by-products obtained from agricultural were considered as the major source of the biomass in India. The crops which mainly constitutes for high biomass were Rice (158.89 MMT), Wheat (148.52 MMT) and several Cash crops (156.44 MMT) apart from other sources like Maize, Pulses, Bajra and Jowar which also contributes significantly (Fig. 2).



	Rice	Wheat	Maize	Pulses	Bajra	Jowar	Cash Crops
Net biomass potential	84,118	118,816	30,765	43,216	13,693	12,862	125,154
Used biomass	74,772	29,704	7,691	10,804	3,423	3,216	31,288
Total biomass/gross potential	158,890	148,520	38,456	54,020	17,116	16,078	156,442

Fig.2 By-products supply of biomass from agricultural crops

The type of conversion processed used for conversion of the biomass to energy as identified in India were mainly Pyrolysis (57%), Gasification (29%) and Combustion / Anaerobic digestion (14%) (Fig. 3)

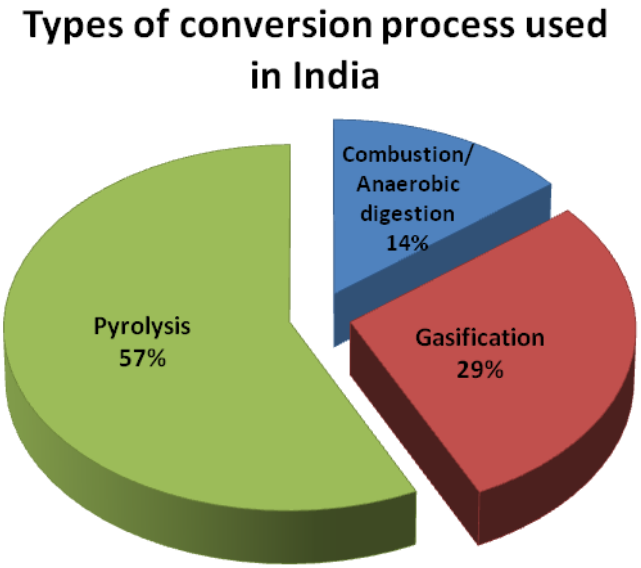


Fig. 3 Types of conversion process used in India

Regarding the Category biomass from wastes, there was no consolidated information on availability of biomass from wastes from India. There are couple of academic reports but limited to specific geographical area or study making it difficult for any extrapolation to have an idea at the national context. However one report published by Central Pollution Control Board (CPCB), Ministry of Environment and Forests, Government of India, with the assistance of National Environmental Engineering Research Institute (NEERI) indicated a survey of solid waste management in 59 cities (35 metro cities and 24 state Capitals of the country. As the data was specifically based on urban cities, the data did not reflect a representative scenario for the entire.

Another report published as “Sustainable Solid Waste Management in India” by Ranjith Kharvel Annepu, Columbia University in the City of New York, sponsored by the Waste-to-Energy Research and Technology Council (WTERT) and which have taken the reference from updated of “Status of Cities and State Capitals in Implementation of MSW (Management and Handling) Rules, 2000”, jointly published by the Central Pollution Control Board (CPCB) and the National Environmental Engineering Research Institute (NEERI), was taken into consideration. According to the report among the four geographical regions in India, Northern India generates the highest amount of MSW (40,500 TPD or 14.8 million TPY) constituting around 30% of all MSW generated in India. Among the states, Maharashtra (22,200 TPD or 8.1 million TPY) tops the list.
However for any waste valorization, only the biodegradable fraction of the MSW needs to be considered. It was observed in reports that the biodegradable (organic) fraction present in the MSW is varied. Thus to consider a figure of waste availability from municipal solid waste of the country, an average figure of 54% was taken into consideration. It was

estimated that the total available biodegradable fraction of waste that can be generated from the country would be estimated at 25542726.84 TPY (Table 2).

Likewise, there was no central data base available for sewage sludge. The reports of CPCB indicated the total sludge generated from several major cities and towns of India but still unable to provide the complete picture of the sewage generated. Thus an extrapolation was carried out for sewage sludge generated for the country. For this a sum of sewage generated in class-I and class-II cities of India was taken from the report published by Central Pollution Control Board (CPCB) "Control of Urban Pollution Series: CUPS/70/2009–10". The calorific value of dried sewage sludge is 13.8 MJ/kg. Hence, the energy content was calculated by multiplying the total sewage generated with the calorific value. The power potential was calculated by converting the energy content from MJPD to MJ/s. Since, 1MJ/s= 1MW. Thus the total sewage sludge generated in Indian came to be 1420.8126 TPD and its expected Power potential estimated was 226.94 MW (Table 1).

Table 1. Total sewage sludge generated and Power potential in Indian states

State	Total sewage generated (MLD)	Total sludge generated (TPD)	Power Potential (MW)
Andhra Pradesh	1978.19	98.91	15.80
Assam	386.60	19.33	3.09
Chhatisgarh	391.29	19.56	3.12
Goa	23.68	1.18	0.19
Gujarat	1908.47	95.42	15.24
Haryana	670.21	33.51	5.35
Himachal Pradesh	28.94	1.45	0.23
Karnataka	2023.77	101.19	16.16
Kerala	806.49	40.32	6.44
Madhya Pradesh	1379.62	68.98	11.02
Maharashtra	10200.02	510.00	81.46
Manipur	26.74	1.34	0.21
Meghalaya	32.09	1.60	0.26
Mizoram	5.71	0.29	0.05
Nagaland	14.98	0.75	0.12
Punjab	1685.66	84.28	13.46
Rajasthan	1530.16	76.51	12.22
Tamil Nadu	1261.88	63.09	10.08
Tripura	24.00	1.20	0.19
Uttar Pradesh	3851.71	192.59	30.76
Uttarakhand	186.04	9.30	1.49

Source: CPCB report "Control of Urban Pollution Series: CUPS/70/2009–10"

Table 2. Total MSW generated and Energy potential in Indian states

Type of Biomass	Biowastes (biodegradable fraction) in TPD	Energy generated out of waste (MW)
Andhra Pradesh (A.P.)	1676	19.274
Arunachal Pradesh	18	0.207
Assam	246	2.829
Chhattisgarh	725.4	8.3421
Goa	36.45	0.419175
Gujarat	1592.722	18.316303
Haryana	1367.28	15.72372
Himachal Pradesh	31.89	0.366735
Karnataka	865.2	9.9498
Kerala	229.36	2.63764
Madhya Pradesh (M.P.)	1027.8	11.8197
Maharashtra	10002.15	115.024725
Manipur	72	0.828
Meghalaya	137	1.5755
Mizoram	86	0.989
Nagaland	20	0.23
Punjab	1010.88	11.62512
Rajasthan	2234.7	25.69905
Sikkim	19	0.2185
Tamil Nadu	1862	21.413
Tripura	114	1.311
Uttar Pradesh (U.P.)	1691.13	19.447995
Uttarakhand	67.29	0.773835

Source: Sustainable Solid Waste Management in India" by Ranjith Kharvel Annepu, Columbia University in the City of New York (2012) and Energy recovery from municipal solid waste (urbanindia.nic.in/publicinfo/swm/chap15.pdf)

It can be summarized that in India, the direct biomass which comes from field mainly included the sugar and oil crops. As India produces nearly 370 million tonnes of biomass (Chauhan 2010). Being an agriculture-based country, one of the non- conventional sources of energy in India, is bio residue or biomass that is available mainly as a by-product of crop production and agro-industries. The proper utilization of agriculture residue

for power generation has been shown by the states of Karnataka, Andhra Pradesh, Maharashtra and Uttar Pradesh in-spite of the fact that the state of Punjab and Haryana are amongst the highest crop producing states. It has been observed that there is an increasing trend of burning the crop residue (husk and straw) by the farmers in Haryana and Punjab. This leads to the reduction in the surplus availability of biomass. Therefore, there is a pressing need to channelize maximum surplus biomass for power generation. The conversion process which is utilized in the country for biomass into energy conversion is mainly through pyrolysis. There is vast potential for energy generation from waste in India as municipal waste generated in the country comes from varying sources and disposed in a local landfill site. Moreover, there were not proper record from authenticated sources from textiles, leather, food and fruit processing industries which may also account

for the significant amount of bio wasted generated in the country, which are not included in the inventory sheet due to lack of authenticated source for waste from these sources. The sewage generated in India was accountable but the further treatment to form sewage sludge was again missing in the reports from authenticated sources, thus extrapolation was carried out for estimating it. Likewise, in India the biomass from forest was not taken into consideration as forest in the country comes under resource security policies, thus considered as conserved. The tree outside forest (TOF) data was also not compiled in any national reports which can provide us the overall figure of the biomass available from this source thus missing in Indian inventory sheets. Although, some information was collected at state level survey, but that also have high consumption demand as a fuel wood in India, thus not available as surplus.

Conclusions

SAHYOG biomass inventories contain the updated information on the availability of biomass in Europe and India. However, setting up both EU and Indian inventories revealed that because of lack of relevant data in various databases consulted for this purpose, it is really a challenging task to achieve a complete and reliable picture of biomass availability. Indeed, datasets in official statistical reports are not always complete or contain mainly highly aggregated data. For example, in the case of biomass from forestry in India, the information is very limited due to the fact that forests come under resource security policies and are considered as conserved.

An analysis of the EU and Indian inventories demonstrates similarities as well as differences in the availability and usage of renewable biomass for energy, chemicals and materials. Being an agriculture-based country, India derives most part of its potential biomass from agriculture by-products, whereas in the EU huge quantities of biomass originates from forestry. A common feature is that in both EU and India, a great part of the available biomass from forestry, agriculture, and biowastes remains unexploited. In addition, due to data heterogeneity, it is not always possible to directly compare biomass availability in EU and in India for specific subcategories. However, under the framework of SAHYOG project, the work on the ongoing research for new data will be continued to fill in the gaps in the inventories. An accurate analysis of the results for both SAHYOG inventories, will finally outline the EU and Indian priorities in biomass utilization and technology implementation.

Based on the results of inventories, specific research cooperation activities between stakeholders from EU and India will be implemented. The information provided in the SAHYOG biomass inventories will help to define common fields of interest to maximize EU-India collaboration and will constitute an important instrument to develop the joint Strategic Research agenda and the future R & D Roadmap in the field of biobased industries.

Acknowledgements

We would like to acknowledge all the colleagues and experts in India as well as in Europe, who provided information, materials, data and suggestions that helped us a lot in organizing this work.
The authors of this report would like to thank the support and a very valuable help provided by Dr. Daniela Claps (ENEA, Italy) and Dr. Piyush Joshi (TERI, India) in preparing this report. Valuable suggestions and help provided by Dr. Vito Pignatelli during the whole course of this work is also gratefully acknowledged. Special thanks are addressed to Dr. Nicola Colonna, who contributed significantly in providing information on the calculating the actual available crop residues in Italy.

Annexes

The inventory datasheets (Excel sheets) prepared for all the European countries and the Pan India Biomass inventory from India side are attached with this report.