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4.2 Strategic Research Agenda supporting the Roadmap

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Leading Authors:

Kees Kwant, Rebecca van Leeuwen, Ludo Diels, Kathy Elst, Neeta Sharma, Silvia Tabacchioni, Priyangshu Sarma, Piyush Joshi, Reeta Goel, Neera Sarin, Rob Bakker.

Co-Authors:

Deepak Pant, Luigi Chiarini, Harshita Negi, Divya Srivastava, Heike Schneider, Karin Metzlaf, Rupam Kataki, S. Venkata Mohan, K. Amulya, M. Annie, R.S. Chutia, R. Saikia

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The objective of SAHYOG is to actively and effectively link research activities implemented within EU research programmes and related programmes by Indian national institutions in the fields of biomass research and bio-waste conversion to prepare a Strategic Research Agenda and a roadmap for the advancement of RTD with mutual benefits.

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WIP Renewable Energies, Germany

SAHYOG Coordinator Contact:

Neeta Sharma
ENEA Research Centre, Italy
E-mail: neeta@enea.it
Tel: +39 0835 974603

SAHYOG website: http://www.sahyog-europa-india.eu/

Department of Biotechnology
Ministry of Science & Technology,
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SEVENTH FRAMEWORK PROGRAMME

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1. Introduction

This Strategic Research Agenda compiles the shared vision for the EU and India on the latest developments in the bio-based economy, and the research needs in this context. It defines specific needs and possible ways, scientific expertise research tools needed, the size of demonstration and pilot plants etc. to enhance the bio-based economy

1.1 Background information

This document has been prepared in close cooperation with representatives from leading research organisations, policy makers and the industry leaders from both India and the EU to foster the implementation carried out by industry, and to achieve a realistic agenda.

Representatives (including industry) were invited to the various stakeholder workshops in Europe and India, where a number of recommendations were formulated. In India, industry is organised under the Confederation of Indian Industries (CII). The CII works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes. While in the EU industry collaborates in the so-called European Technology Platforms (ETPs): Suschem, EuropaBio and Biofuels. European Technology Platforms (ETPs) are industry-led stakeholder fora that develop short to long-term research and innovation agendas and roadmaps for action at EU and national level, to be supported by both private and public funding. Relevant platforms in India have also been identified, where CII http://www.cii.in was a main partner. The Strategic Research Agendas from both platforms were used as input when drafting this Strategic Research Agenda.

In Europe Joint Technology Initiatives (JTIs) are a means to implement the Strategic Research Agendas (SRAs). The official launch of the new Joint Technology Initiative Biobased Industries (http://biconsortium.eu/) took place in the presence of Mr Barosso and Maire Geoghegan Quin on 9th July 2014, which was the official start and the first launch of coordinated calls according to the PPP-principle.

In addition to this initiative the EU launched the Research and Innovation Strategy (RIS3) for Smart Specialisation indicating that each region must invest in a smart specialisation, and that the best key players will be brought together via clustering.

Further support will be created by the EIT, European Institute for Innovation & Technology that stimulates and facilitates collaboration in education, research and innovation between universities, research institutes and industry and also some of the KICs (Knowlegde and Innovation Centres) will support this.

Together with the key enabling Technologies (of which the bio-economy is one of the six topics), the bio-economy will play a very strong role in all these initiatives, and will further lead to specialisation and support to a circular economy.

Many of the activities carried out within the SAHYOG project, including the numerous stakeholder meetings held in both Europe and India have provided an excellent scope for the strategic research recommendations. (Please refer to the strategy and recommendations at the end of each Chapter, and to the overall conclusions at the end of this SRA). In order to capture the most important recommendations, an online survey was carried out amongst all relevant stakeholders in the bio-economy including industry, policy makers, research organisations in both Europe and India . Close to 250 persons responded to the survey. It was generally felt that this survey was a good initiative to get opinions from multi-disciplinary research concepts, such as sustainability. It will help to guide funds to proper fields of research on a priority basis. A detailed analysis of the online survey will be published separately. Some quotes from the survey are given below:

"….There are some strategic areas where India/EU collaboration can be helpful".

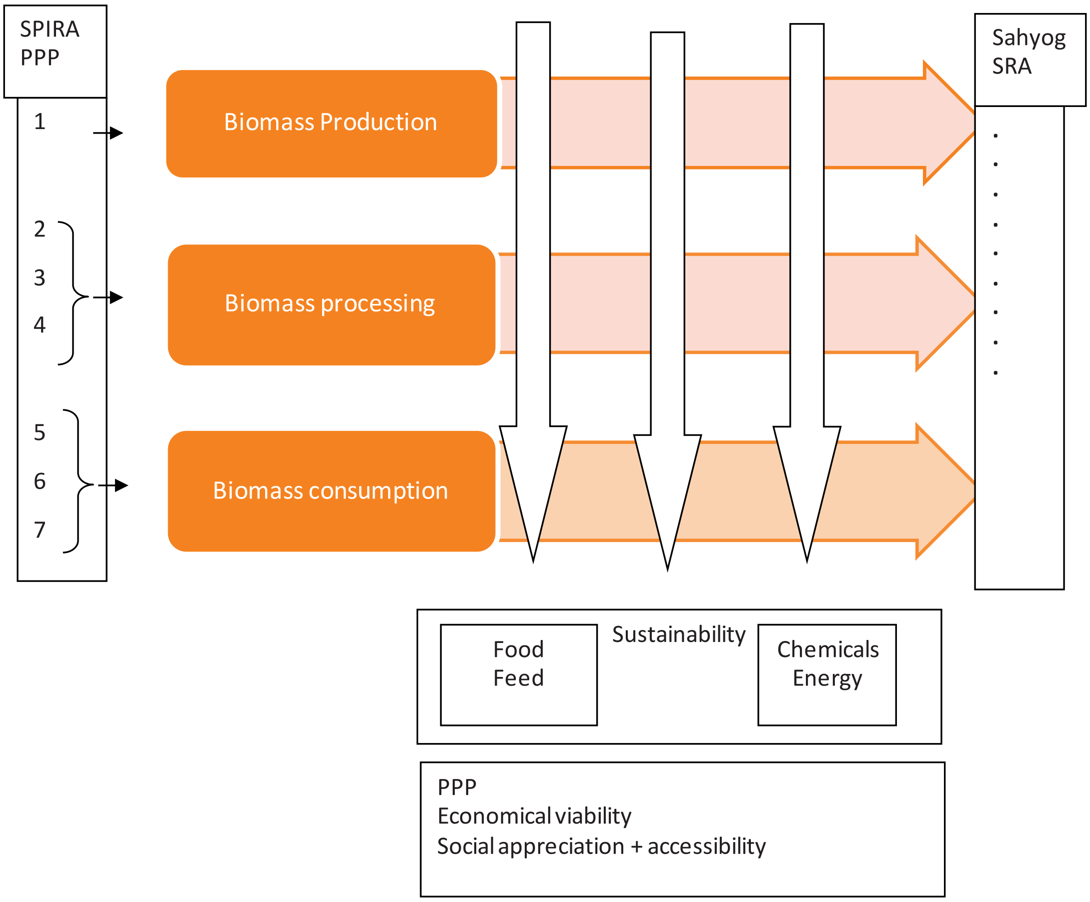
"….Strengthening the bio-based economy in a holistic manner would go a long way in the overall growth of the country".

"…India provides big markets, agro-resources and potential resources in municipal waste. A partnership of EU and India in identifying resources, developing technologies and realising business opportunities is for sure a great option to push the global bio-economy".

"'….The biomass supply chain management is the key to resource management, sustainability and long- term value creation in the bio-economy. This needs to be the model for development of the bio-based economy".

1.2 Structure of the Strategic Research Agenda

The structure of the SRA is depicted below. It consists of three main chapters, each describing the present status and strategic research needs for collaboration between Europe and India in specific domains. Chapter 3 focuses on feedstock including biomass and waste production, Chapter 4 on bio-refineries (or alternatively biomass/waste valorisation and technologies), and Chapter 5 on products, markets and policies (but with a focus on the research needs related to these topics). Each chapter deals with the description of the vision relevant to the Chapter, the current status (state of the art & problems & challenges), description of the strategy and the recommendations for R&D. A lead author and a team of co-authors were assigned to each Chapter from both India and Europe. A number of brainstorm sessions followed by telephone conferences and regular collaboration between the authors was necessary in order to come to a coherent, comprehensive strategic research agenda.


SPIRA
PPP
1
2
3
4
5
6
7
Biomass Production
Biomass processing
Biomass consumption
Sahyog
SRA
Food
Feed
Sustainability
Chemicals
Energy
PPP
Economical viability
Social appreciation + accessibility

2. General Vision towards a Bio-based Economy in Europe and India

2.1 Background

Our fast growing and developing world is facing problems such as environmental deterioration, biodiversity decrease, climate change and scarcity of resources (including energy and water). It is clear that we have to move from a linear economy towards a circular economy and that by relying solely on renewable resources we will not be able to tackle the afore mentioned problems. Renewable resources are resources that can be re-used without harm to the environment, without reduction in quality and without downward cycling. Even keeping the value of the resources as high as possible will become the big challenge.

In the broad scope of clean technology and renewable energy the bio-economy can be a big support as it is a perfect example of a circular economy. It brings CO_2 into a circular approach with no increase, nor decrease. Only smart approaches will lead to a CO_2-decrease balance and this will be the ultimate goal of the collaboration. Europe and India believe that they can both partly rely on this bio-economy although they have different skills and challenges, making the collaboration needs even stronger. The first target therefore will be to set up a real bio-economy system adapted to the first needs and challenges. It is proposed to look to the bio-economy from three points of view being the biomass production, the biomass processing or bio-refinery and finally by looking to markets, society and legislation.

2.2 Needs and challenges in Europe

Europe is facing reduction in production capacity and its still strong, chemical industry is searching for new resources based on biomass (indirect capturing of CO_2) and CO_2 (direct capturing). Europe (at least some countries) has the best waste management systems in the world and has a definite scarcity in primary materials. On top of that it has a relatively good environmental legislation. Europe is the cradle of the chemical industry (based on coal, later on fully developed on petroleum), but also of bio-technology with a strong green bio-technology, a relatively good red bio-technology and a strong focus now on white or industrial biotechnology. It does not have a huge access to gas (natural as well as shale gas) as in other places in the world. Indeed some places in the world will rely on C_1 – C_3 hydrocarbons (gas) for energy and chemicals and others must rely on very complex oxygenated (including also N, S, ...) chemicals from biomass. In this choice biomass and especially residues can become key in the European approach. The challenge will be to make use of these functionalities via the reduction in energy costs in conventional oxidation of hydrocarbons or via the innovative use of these functional groups in new applications and materials.

Europe with 110 million ha of crop land, 55 million ha grass land and 178 million ha of forests and some 100 million ha others will only be able to grow by re-using abandoned and/or contaminated land, especially in the former East-European countries. Further it will focus on breeding of multi-purpose plants (in order to use the biomass in a more complete value chain) and the still high yields will continue to increase. Large efforts will be made in the value chain development of the biomass treatment in a bio-refinery with a complete and optimal use of every molecule and the highest possible value and with more attention to chemicals and materials than to energy. Energy will be seen as the end of the cascade approach and as the end of the life cycle of materials. Energy will strongly be seen in connection with sewage treatment and recovery of it from water and from dirty waste (not fractionable). The bio-refinery will have to evolve into an integrated one with intensified processing including gas and waste-water management.

The market will develop into a more bio-based molecules and materials one and especially to the development of new innovative molecules (polymers, resin, coatings, glues, plasticisers etc.). The full value chain development will strongly lead to process intensification. This means that more processes will turn from batch to continuous. Some of the processes can become micro- or milli-production based. Flexible, decentralised and robust, fast to market systems will be installed geographically where the market needs are, where the resources are or where some utilities as rest heat, steam, CO_2, H_2 or whatever is produced.

Legislation will be supportive of certification, turning waste legislation into material legislation and the needs for a legislation that will be less in favour of energy applications in the primary use. Markets will also develop further into recycling and re-use with strong efforts on energy reduction between the primary and the secondary (based on recycling) process. Recycling will be based on renewing the chemicals allowing to make whatever is needed in the next cycling round.

2.3 Needs and challenges in India

The Indian population is so fast growing that the first concern is to feed more than 1.5 billion people by 2050. In the same period (2010 – 2021) we see an increase in large cities (> 100.000 people) and small towns (< 100.000 people) from 377 to more than 540. At the same time we see that the rural population will reduce from 833 million to 810 million people, which is almost stable, indicating that growth will come in urbanisation. There will be a large increase in the need to access food in a proper way (processed) amongst those living in cities. Those living in the rural areas, many of whom are already suffering from malnutrition, will still have the same needs for food as they have now. Apart from food we see that 23.5% of the primary energy needs in India are currently coming from biomass (about 750 TOE) which can probably grow to 40%. It indicates that food/feed and energy will become the focus areas for India.

Indeed biomass can replace coal for energy production (2 GW to 30 GW), biogas can replace CNG/LPG (7.3 bill cum to 44 bill cum), bioethanol can replace gasoline (1 million ton to 10 million tons) and biodiesel can replace diesel (0.05 million ton to 2 million tons). This all will mean that the share of biomass in renewable energy will presumably increase from 7 % to 15%.

From the availability point of view we see that forests are covering 70 million ha of which 5 million will be improved for coverage and an extra 5 million ha will be planted. In agriculture crop land covers around 141 million ha + an extra 55 million lying fallow for more than 6 months. The grazing (grassland) surface is about 50 million ha. Lack of optimised seeds, lack of water or proper water management and lack of fertilizer makes that yields are decreasing whereas under proper management the yields can certainly increase by a factor 3 – 4. On top of that more that 50 million tonnes of rice straw is burned (especially in the Punjab) in the field leading to huge CO_2 emissions and particulates. This can be used as energy source. In addition a lot of fruits and vegetables never reach the market due to improper storage and processing capacity. 283 million bovine animal produce apart from 120 million L milk (200 million in 2021) more than 1250 million tons of manure (18%DS), and 500 million poultry birds produce an extra 10 million dry manure (75% DS). Horticulture, nowadays at 210 million tons, but with a large planned expansion (target 350 million tons) in order to improve nutritional quality, is targeted to 350 million tons (at least). The food processing waste of it will lead to an extra 80 up to 140 million tons of waste. Municipal solid waste is more than 150 million tonnes with more than 50% bio-waste. Nowadays on top of that it covers 60 thousand ha of landfills emitting landfill gas (greenhouse gases). Sewage is mounting from 40 billion litre/day to 50 billion litre/day at least. It will be responsible from more than 10 million extra sludge and more than 20 million ton CO_2-emissions. A still non-explored possibility is the 7400 km long coastal area of India that can provide production sites for cultivation of large amounts of algae and especially macroalgae, rich in proteins, sugars, oils and lipids and many other compounds as well as energy source.

This availability paragraph shows that the low hanging fruits are the use of all kinds of residues in a smart way. In the same time production and logistics and storage will increase the biomass (i.e. food amounts) and will later on generate an extra residue stream. The first biomass use can go to energy, but improved solutions must be developed to upgrade these waste streams by pre-treatment and fractionation (extraction) into added value compounds.

We indeed see that the production of biomass will be key in the whole process. Primarily the processing will focus on food processing in order to make better conservation processes. Indeed nowadays farmers tend to produce cereals because the storage of it is at least somewhat more reliable than the storage of vegetables or fruits. Later on India can go to the full integrated bio-refinery with the help and collaboration with Europe. As far as markets are concerned a strong food supply market will develop, accompanied by a bioenergy market as a side product. In the long term India will be able to use its large biodiversity and develop high added value products from very special and added value plants leading to a fully needed market. The lower hanging fruits of biodiversity are based on the huge potential of varieties and species that can be investigated for instance in the field of algae, seaweeds, bamboo, jatropha etc. This is separate from the potential in fragrances, aromas, medicines producing plants.

From a policy point of view the right decisions must be taken to support the food production and increase in yield, to give higher value to bio-energy and to support not only the bio-energy but also the conversion into added value as chemicals and materials with the support from Europe. India has the strongest expertise on semi-arid and dryland agriculture (sorghum and millet) in the world. This expertise can be used for parts of the Indian agriculture intensification and can become standard for other similar regions in the world (especially in Africa).

In fact the proper use and management of biomass will lead to a huge environmental effect. The burning of rice straw causes air quality problems up to in Delhi; in rural areas > 400 people die due to poor indoor air quality (result of cooking on fresh wood); waste heaps and dumps are emitting greenhouse gases; and waste- water is the biggest problem. We can calculate that proper municipal bio-waste and sewage handling would reduce the CO_{2eq} emissions by 150 million tonnes which is the equivalent of more than 25 large coal fired power plants and also the loss of the equivalent energy potential. Only the biodegradable municipal solid waste would be an equivalent of 2500 – 3750 Mm^3 biogas. So, these environmental managements, carried out in a smart way, can lead to a diverse group of energy production systems. In order to do so, a large political will and support will also be necessary in order to thrive towards the right decisions.

2.4 Towards a strategy

At the feedstock level

Europe

In Europe the main available biomass resource is forestry waste followed by domestic and industrial organic waste, sewage, and cereals residues. For plants grown purposely for the bio-economy there is potential for other cereal plants or perennial grasses, for wood (especially Short Rotation Forest or Short Rotation Coppice) and algae.

Europe produces > 220 M tonnes of food waste. According to the calculations made within the SAHYOG biomass inventories, EU 27 produces 7768 Ktoe per year of sewage sludge (total energy content of available biomass). and 251 M tonnes of domestic waste, of which 35% is kitchen and yard waste and 22% is paper and card waste

The potential improvements by better agriculture production, nutrient and water management as well as the development of new crops (e.g. multipurpose crops) and use of dedicated energy crops (Switchgrass, Miscanthus, Reed canary grass, Giant reed grass etc.) will all lead to higher biomass yields, higher content of added value compounds and drastically change the agriculture landscape with minimum impact on biodiversity, environment and climate. The crops mentioned are strongly related to lignocellulose production. At the oil level cardoon and related crops will develop in the Mediterranean countries.

Forestry is the most important biomass resource in Europe that provides the maximum contribution of biomass (about 54% of total ktoe) for energy, chemicals and material use.

Europe already produces about 428 million m^3/yr of round-wood, which is only 60 to 70% of the annual wood increment. It is suggested for sustainability reasons to keep this to around 60%. According to the Karlsruhe Institute of Technology (KIT), Europe can also have a potential of 45 M tonnes of algae (produced at a cost < 2000 $/ton). Europe will, during the coming years, (especially after 2017 when the sugar quota will be stopped), increase its sugar production by a factor of at least 3 and release in that way a cheaper industrial sugar.

Besides this Europe will focus on the recovery of proteins in order to become more self-supporting at the protein level. This will be done by recovery of proteins from grasses (see higher) and from sugar beet leafs (see also higher).

Europe will focus on the development of multi-purpose plants and on plants with modified lignin structure in order to allow more mild lignocellulose disruption and lignin valorisation.

An evaluation of the data collection for SAHYOG inventories demonstrates that only 40% of the 27 EU Member State inventories are complete as far as total available aggregate data (tonnes/m3) is concerned. Furthermore, all the data under the biomass resource category “Forestry” is complete, whereas in case of “Agriculture and Bio-waste”, only around 50% data is found to be completed in case of EU countries, as far as total aggregate data are concerned.

India

The most abundant and available feedstock for India will be the domestic and industrial (sugar mills, slaughter houses, paper mills, dairy plants, sago factories, tanneries, fruits and vegetables processing centres etc.) organic and biodegradable waste fractions. Increased water treatment will lead to extra sewage sludge. Further cereal residues will be used in place of burning as nowadays.

As the food processing industry will grow tremendously (and will have to grow) in the coming years (at the moment only less that 10 % of vegetables and fruits are really processed in India) a huge increase in food waste (wet residues) can be expected.

As well as in Europe new developments of cereal plants and grasses will feed the bio-economy. Sugar cane improvement will lead to higher yields and will be combined with sweet sorghum and tropical sugar beet to extend the mill processing periods and to improve land and water management.

At the forest level there are only limited actions possible, but bamboo production will increase and deliver lignocellulose for energy and other applications.

India will focus on micropropagation and seed improvement as well as on water (irrigation), fertilizer and land management (e.g. combination with solar panels reduces high temperatures and irrigation with water used to clean the panels). Also the development of salt and drought resistance will become priority.

India will develop a special focus on oil plants as Jatropha, castor beans and *Salicornia bigelovii* (growth on salt marshes). Along the coastal line micro- and macro algae will have a huge production increase with industrial level production sites on non-arable land and using seawater.

At the bio-refinery level

Europe

Bio-refineries, as full integrated biomass processing factories, will develop in different directions. Wet waste and sewage will further be treated into biogas and fertiliser with more attention to upgrading of the biogas for direct use in the natural gas pipelines.

Europe will see a strong development of cereal waste and cereal plants (grasses) based bio-refineries producing cellulose, hemicellulos and lignin. These three main compounds will further be processed into new molecules. Especially in the case of waste attention will also be given to the recovery of inorganics from these feed-stocks. Strong research will be required in the lignin valorisation by transforming it partially into bio aromatic molecules and using the left over lignin structures as energy source. Some high molecular weight lignin sources will also be transformed into high added value nano-carbon fiber applications. Wood will be processed in similar bio-refineries.

The increase in sugar production after 2017 will lead to several sugar based bio-refineries making alcohols, organic acids, polyols, aromatics etc. Bio-refineries will also develop into process intensified systems leading to higher product titres, higher productivity and lower downstream processing costs.

At the oil level new Lc fatty acids, dicarboxylic acids and derivatives as esters and epoxides will be developed for new material developments. Side products from this processing will also be developed.

India

The primary concern of India remains the level of food production and in that way food (especially fruit and vegetables) processing. In order to improve storage and transport will have the highest priority. This will lead to huge industrial processing waste streams (see also feedstock level).

India will fully develop these wet biomass and wet biowaste processing via pre-treatment for recovery of added value products and improvement of biogas production.

India will collaborate with Europe on the cereal and wood streams and will develop a strong algae based economy. This algae economy will also be the basis for a bio-oil chemistry and development.

Finally India will further develop its medicinal plant potential via extraction, fractionation and purification of medicinal molecules from a large diversity of plants.

At the market level

In India the improved food quality and quantity will help to further develop the food processing and trading industry as well as the retail business.

Europe will also focus on food additives and prebiotics to be extracted from food processing streams.

India will create a strong bio- based energy market especially via biogas plants, but also in power generation and biofuel production. Europe will focus strongly on renewable chemicals and on innovative molecules such as e.g. new bio-aromatics with special functionalities. India will create a new market for plant-based medicinal molecules. There will be common developments towards the next generation of biofuels and biomolecules.

3. Biomass and Biowaste Feedstocks

3.1 Vision

The further development of the biobased society relies strongly on the availability and secure supply of suitable renewable feedstocks from agriculture, forestry and/or waste. Europe and India, with a land area of respectively 418.2 Mha and 297.3 Mha, have differences in land use and therefore also availability of renewable resources. Whereas in Europe the agricultural area (41.7%) and forests (42.3%) have nearly equal shares, in India the agricultural area (60.5%) is dominating. Moreover, significant differences exist in the exploitation of forests. The forests in Europe are largely available for wood supply, whereas in India they are largely protected and much less accessible. In India, significant amounts of wood comes from trees outside the forest. This makes agriculture the dominating source of biomass in India, whereas both agriculture and forestry are important for Europe.

In Europe, a steady increase in the utilization of biomass from energy and arable crops for energy use from the year 2006 to 2010 has been observed from consulting National Renewable Energy Action Plans (NREAPs) reports. Thus, several issues must be considered to reduce the negative impact of these cultivations on natural ecosystems and the competition on land use for production of food, energy and biobased materials. Indeed, Europe, as an important food producer need to develop strategies to efficiently secure and increase its agricultural output for food necessary to increase productivity of non-food uses and to open up new avenues for use of biomass for the sustainable bio-based economy chains and to face the instability of biomass supply. Smart approaches should be developed for the better use of limited agriculture land in Europe and to improve and secure soil quality, to counteract environmental threats such as erosion, salinization and contamination. Yield increase and stabilization has to come via selection of more robust and resilient crops. Efficient strategies should be developed to further decrease losses in the production chain, to reduce environmental impact, increase ecosystem services and enhance biodiversity. The SAHYOG biomass inventory indicates a major biomass potential in the form of agricultural residues (straw, other?) mainly available in the countries with a large agricultural sector and high agricultural production such as France, Germany, Romania, Spain, Italy, Hungary, Poland and United Kingdom. However, there are some limitations for their use for bio-refinery. A number of issues must be considered: resources (quantity, multi-annual variation), logistics (energy demand in the area, storage, security of supply, harvesting period and transportation distance), technological (available technologies), economical (costs of resources and cost of energy) and social issues (perception and attitude of farmers).

In Europe, most of the biomass potential is from forestry. The major part of it comes from the countries with a large forestry sector: Sweden, Germany, France, Finland and Poland Currently, in addition to its direct utilization as a building material, the major uses of wood are also for paper production and generating heat and energy. It is important to have an estimation on its actual use to further utilization in chemicals, materials and biofuel production. NREAPs reports indicate an increase in the availability of forest biomass for energy use in Europe of more than 50% of the countries showing a significant increase in direct supply of forest biomass from the year 2006 to 2010. However, biomass available quantities should be estimated with respect to the optimum transport allocation areas, indeed, it is important to take into account that this biomass would not be fully used, as there are technical limitations (e.g. slope) which limit the collection process etc. Regarding

biomass from waste in Europe most of the information on different subcategories of biowaste is available for the countries: United Kingdom, Germany, Romania, France, Italy, Netherland, Poland, Sweden, Denmark, Belgium and Spain. However, the estimation of the available biomass from waste depends not only on the total production of waste, but also on whether there is a collection system enabling the registration of the total amount of waste and in case of MSW does not always reflect the number of inhabitants. Waste management is surrounded by a number of rules, regulations that are quite different among different MS. Big differences exists also on recycling and reuse of this biomass category. For instance, present recovery rate of sewage sludge is still very low in most EU countries which is related to the limited possibilities to recover this waste other than into energy. Currently, most of the sludge is incinerated and/or deposited into land and only a small part is already used for energy recovery. The optimization of waste management system in Europe is necessary not only for energy and materials recovery but also to reduce environmental impact.
Development of biobased economy in Europe needs an accurate estimation of the availability of biomass from agricultural, forestry and waste sectors, their competitive uses, as well as a GIS-based survey of their geographical localization.
In India, biomass plays a vital role especially in rural areas, as it constitutes the major energy source to majority of households. Being an agriculture-based country, India derives most part of its potential biomass from agricultural crops and agricultural by-products (Husk, Straw, and Stover). About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs. Moreover, 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. However, 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. The rate of urbanization in India was 28.7% in 2005 and is expected to rise to 34.5 % by 2015. This situation demands an infallible waste management system to handle the large amount and diverse types of industrial, agro-industrial and municipal wastes. Efficient segregation of waste, transportation and treatment along with awareness and education amongst citizens and smooth functioning of an effective system, pave the way to the entire process of waste management.

However, for production of agricultural produce and sustainable utilization, India should address some critical issues *viz.* Deployment of existing technologies in agriculture, and increasing research in agronomic sciences and breeding technologies, proper supply chain, adequate policy framework, and effective financing mechanisms, regulatory framework information and dissemination. In addition, considering the increasing demands of feedstocks, India have to handle the feedstock competition on biomass for energy versus industrial material use. Thus, there is need to increase the agricultural biomass potential by including opportunity of high yields varieties, energy plantation in the unexploited waste land and diversified crop selection as per the state geographical and agronomical conditions. The underused and unutilized crop produce should be included in the bio-economy chain and the produce of marginal farmers should also be taken into consideration at regular basis. Considering the need for the improvement in agricultural produce the involvement of available lead from ongoing R&D projects, diversified agriculture, crop rotation practices, state-wise diversified germplasm demarcation, improved production systems, phenotyping etc. will be taken into consideration. Concerning biomass from forestry in India, the total growing stock of India's forest and tree outside forests is estimated as 6047 Mm^3 which comprises 4499 Mm^3 inside the forests and 1548 m^3 outside the forests (TOF).[46] Although the annual potential production of wood from forest and TOF is 3.2 and 42.8 Mm^3 but the commercial availability of biomass from Indian forest is not considerable due to policy matter. Concerning biomass from forestry in India, very little information is available from authenticated sources and data on trees outside forest is very limited and no recent information is present in any secondary sources available.

The recent interest in India is on cultivation of Bamboo. India is the second richest country in terms of Bamboo genetic diversity with a total of 136 species under 75 general. The total bamboo bearing area of the country is estimated to be 13.96 million hectare. Recent mapping studies indicate that the total green weight of green culms amounts 169.3 Mton of which 73% green sound and the remaining 27% dry sound bamboo.[45] In India, the usage of bamboo is to the tune of Rs 2043 crore in 2003, and there is the scope to increase the size of the industry by at least 2.2 times.[1]

Though having different immediate goals and needs to be addressed, Europe and India also share common challenges in the field of feedstock production which can be jointly addressed. Most efficient development could come with regional approaches, including active involvement and empowerment of smallholders. Prevention of agricultural losses, decrease soil losses and increase soil quality, optimization of water and Pesticides and plant protection use, identification and development of new, more robust, resilient and multi-purpose crop and better usage of available germplasm and wild species are further common goals. Concerning biomass from forestry, Europe and India show several differences because in Europe forestry is a significant source of biomass for both materials as well as bioenergy production whereas in India most of the industrial roundwood and fuelwood, comes from outside the forests and it is difficult to distinguish between the direct and the indirect sources of biomass from forestry. However, the requirement for forest products in India is growing and will continue to increase due to population and economic growth and efforts should be made to increase the area under forest cover by afforesting wastelands through social and agro-forestry. Common policies between Europe and India could be developed on forest management taking into account to the principles of sustainable development, prevent deforestation, short-rotation forestry, energy crop plantation and biodiversity conservation. A common feature is that in both EU and India, a great part of the available biomass from wastes remains unexploited. The generation and management of waste depends on what activities are going on in society, and also on how these activities are controlled by public authority. Therefore, in order to develop in a more sustainable direction measures are needed to regulate the waste sector and increasing PPP mode and adopting sustainable waste management techniques. This requires common strategies and possible cooperation between Europe and India on better agricultural practices, forest conservation and waste management including collection, registration and recycling should be adopted.

3.2 Current Status

3.2.1 Introduction

The EU-27, with a total geographical area of 432.5 Mha, has a land area of 418.2 Mha that comprises 41.7% of utilized agricultural area (UAA) and 42.3% of forest land. Both agriculture and forestry are very important biomass producing sectors. India, on the other hand, with a total geographical area of 328.7 Mha and a land area of 297.3 Mha, has a nearly similar UAA as Europe, i.e. 179.8 Mha, but only a forest land of 68.4 Mha. Therefore, for India agriculture is the backbone of Indian economy and the main source of biomass production.

Table 1: Comparison in land use between EU-27 and India.

	EU-27		India	
	(Mha)	(%)	(Mha)	(%)
Total country area	432.5		328.7	
Inland water	14.3		31.4	
Land area	418.2	100	297.3	100
Utilized Agricultural Area (UAA)	174.5	41.7	179.8	60.5
Arable land	103.1	24.6	157.5	53.0
Permanent crops	10.6	2.5	12.1	4.1
Permanent meadows & pastures	60.5	14.5	10.1	3.4
Forest area and other wooded land	177.0	42.3	68.4	23.0
Other land	66.8	16.0	49.0	16.5

3.2.2 Current biomass production from agriculture

Land use of the agricultural area and agricultural holdings

Despite the similar UAA-area, its utilization differs significantly between Europe and India. In *Europe*, 41% of the UAA is used as fodder area, of which 34.7% as permanent grassland, 6.2% as temporary grassland and 5.2% as cultivation land of fodder crops. In *India*, on the other hand, only roughly 9% of the UAA can be considered as fodder area, composed of 5.6% of permanent grassland, and roughly 3%[a] dedicated to the cultivation of fodder crops. India has therefore a significantly larger area dedicated to the production of arable food and

[a] No accurate data available, estimate.

industrial crops, i.e. 84.5% of the UAA as compared to only 47.6% for Europe. Both India and Europe have similar areas dedicated to the cultivation of permanent crops, being 6% (EU), respectively 7% (India). Figure 1 and Figure 2 give an overview of the land use in EU-27, respectively India.

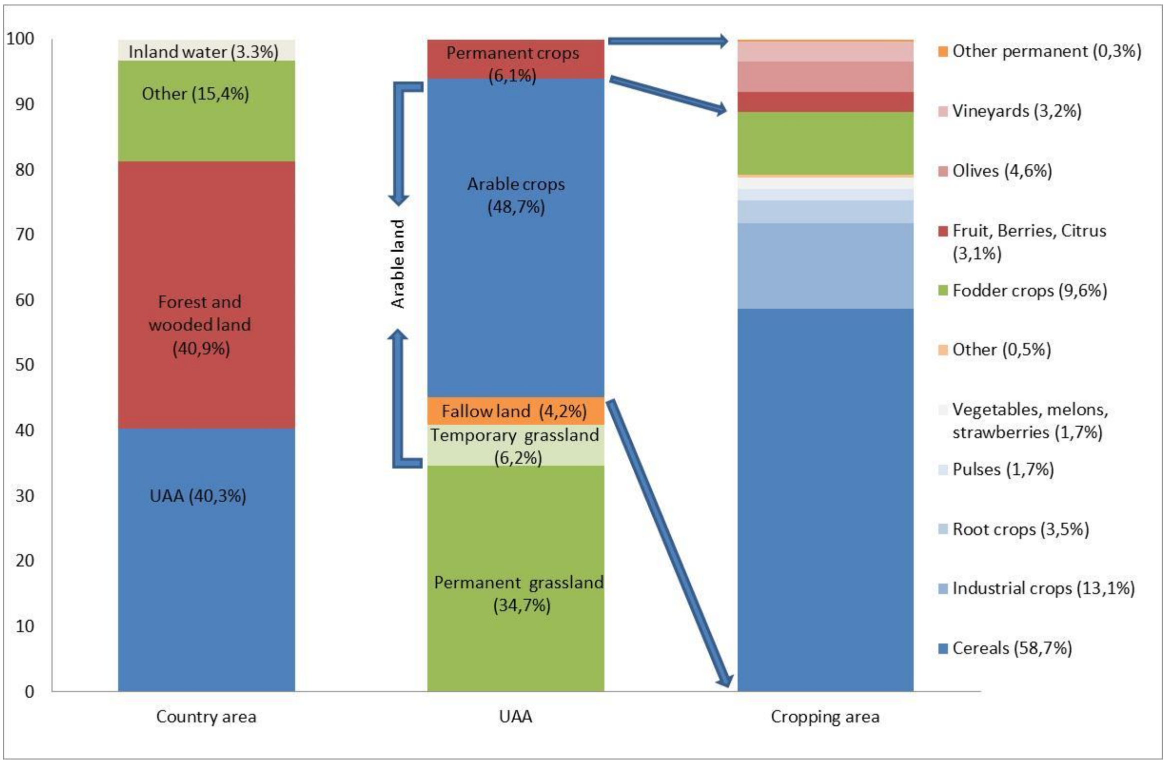


Figure 1: Land use in EU-27 (2010).[2]

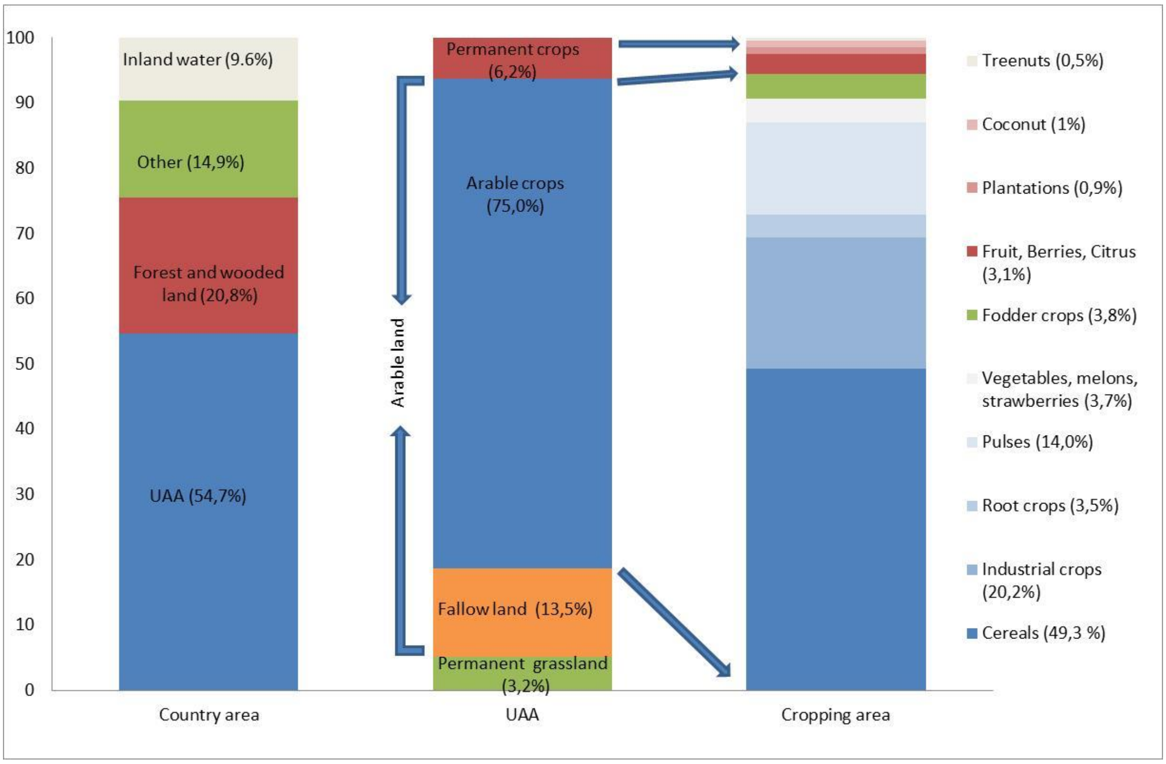


Figure 2: Land use in India (2011-2012).[3,4,5]

Both in Europe as well as India strong regional differences exist in the importance of the agricultural area in the total land use. In Europe, the largest absolute shares of UAA are located in France (16%) and Spain (14%).[6] Some regions in the EU-27 have terrain and land cover that permit a large area to be used for agriculture, as found for instance in the UK, Ireland or Denmark. In others, harsh climate conditions, improper soil condition, dense forest cover or topography limit the agricultural use of land. Examples are for instance Sweden, Finland and Estonia. Overall, agricultural land is the dominant land use all over Europe, except from the northern countries over the 61^{o} latitude north. For India, the following states are the most developed states In terms of agricultural contribution: Punjab, Uttar Pradesh, Madhya Pradesh, Haryana, Bihar, Andhra Pradesh, Maharashtra, West Bengal.

For Europe, it can be assumed that there is practically no future capacity to bring further land into production since currently fallow or set-aside land in the EU-27 is very limited.[7] Moreover, the conversion of natural habitats, such as forest and permanent grassland, to agricultural land is limited by EU directives. This means that food as well as non-food uses of biomass in Europe rely on the present available land and that sustainable use of this land is most essential.

Moreover, several treats exists that may result a loss of the present agricultural area in the EU-27. These are for instance:

- Sealing: In the period 1990-2006, 19 MS lost a potential agricultural production capability due to sealing equivalent to a total of 6.1 million tonnes of wheat;
- Desertification: 14 million hectare of twelve MS predominantly in southern, central and eastern Europe, comprising 8% of UAA, is currently threated;[8]
- Restructuring of agricultural sector related to privatization: substantial drops in UAA were observed between 2003 and 2007 for Romania (10.6%) and Slovakia (9.8%).
- Soil degradation, like salinization, acidification, pollution and organic matter reduction.

Strong differences exists between Europe and India on the organisation and structure on the farms. Whereas in the EU-27, the average size is 14.2 ha, and the number of farms is decreasing, in India agriculture is dominated by an increasing amount of small farms. The average size of the landholding declined with 13.5% from 1.33 ha in 2000-2001 to 1.15 ha in 2010-2011, whereas the number of operational units increased with 15.4% from about 119.9 million to 138.3 million in the same time span. To circumvent the decline in farm income related to the decreasing size, a large number of farm holders have moved to post-harvest and non-farm activities to augment their income.[9]

The main characteristics of the agricultural holdings and the regional differences are summarized in Table 2 (EU-27) and Table 3 (India).

Table 2: Structure of the agricultural holdings in EU-27 (2010).[6]

Holdings	Description	Trend	Regional differences
Number	11.97 million	Decreasing	Mostly located in RO (32%) and IT (14%). Decrease particularly fast in SK, HU, LV, and DE.
Size	Average: 14.3 ha 49% are small (<2 ha) but		Small size holdings are mostly located in RO and I.

	represent only 2% of the UAA. 3% are very large (>100 ha) but represent 50% of the UAA.		Large size farms are mostly located in western EU, very large ones in eastern EU.
Type	Specialist cropping: 25% field crops 20% permanent crops Specialist lifestock: 15% grazing 12% granivores Mixed farming 13% mixed crop-livestock 7% mixed livestock 4% mixed cropping	Stable	Specialist cropping: dominant in Mediterranean & Scandinavian countries. Specialist livestock: dominant in parts of Western Europe. Mixed farming: dominant in most new MS.

Table 3: Structure of the agricultural holdings in India (2010-2011).[10]

Holdings	Description	Trend	Regional differences
Number	138.35 million	increasing	13 states account for 91% of the holdings: UP (16.6%), BR (11.8%), MH (9.9%), AP (9.6%), MP (6.4%), TN (5.9%), KA (5.6%), WB (5.2%), RJ (5.0%) KL (5.0%), GJ (4.7%), OR (4.7%), and CG (3.7%). 88% of the total operated area.
Size	Average: 1.15 ha Distribution holdings: 85.0% are marginal/small (<2 ha) and represent 44.6% of operated area. 0.7% are large (> 10 ha) and represent 10.6% of the operated area.	decreasing	Depends on the state. Among the 13 states with most holdings, PB (3.79 ha) and HR (2.26 ha) have much higher, RJ (3.06 ha), GJ (2.11 ha), MP (1.79 ha) have higher, and KL (0.22 ha), BR (0.39 ha) have lower average sizes. Decreased for almost all states as compared to 2005-2006.

Land use of the crops area (excluding forage and grasses)

As mentioned in the previous section, the utilization of the available UAA differs strongly between EU and India, due to the importance of forage in Europe which is much less prominent in India. As a result, in Europe the gross cropped area is only 88 Mha[11] and significantly less than the agricultural land. India, on the other hand, has significant multiple cropping, whereby two or more crops are grown in the same space during one single growing season. This makes that the gross cropped area, considering the multiple cropping, amounts 193 Mha[11] and is significantly larger than the agricultural land. The cropping intensity, a measure for the multiple cropping, amounts 141% and increased significantly last decades due to improved irrigation systems.

Figure 3 gives a comparison between the EU-27 and India on the harvested area as used for each type of commodity, including food (and related feed) and industrial crops, but excluding forage crops only dedicated for feeding purposes.

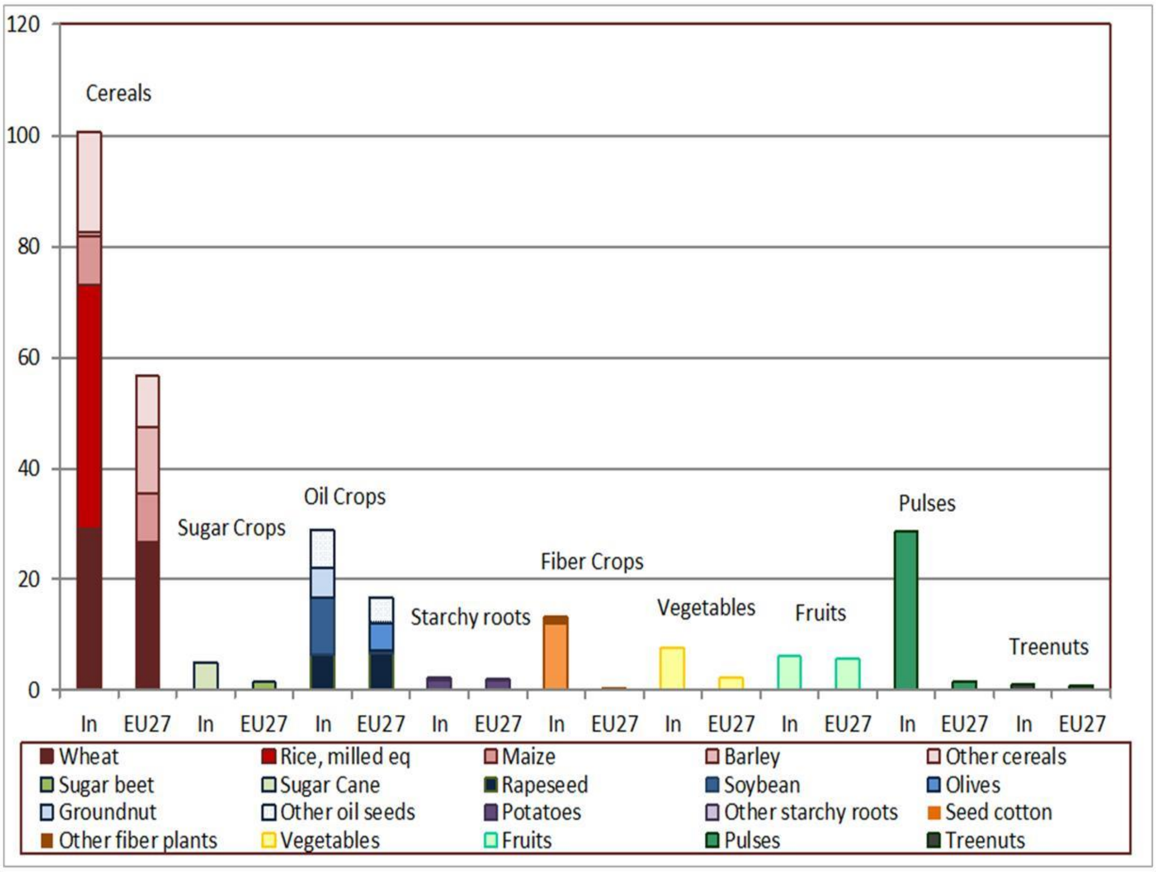


Figure 3: Comparison of the areas harvested for the different crops (in Mha).[12].

The figure indicates that both in India and EU-27, the crop area is dominated by the production of food grains, mostly cereals in EU, but also including a significant production of pulses in India. When excluding forage crops, the food grains cover roughly 66% of the crops area in both India and EU-27. In EU-27, the area related to food grain production is dominated by wheat (45%), followed by Barley (20%) and Maize (15%). Pulses only account for 3%. In India, the area used for food grain production is dominated by rice (34%), followed by wheat (23%), pulses (22%) and maize (7%).

Oil crops production also takes a significant portion of the crops area, being 19% in EU-27 and 15% in India. In Europe, the area dedicated to oil crop production is dominated by rapeseed, mostly used for biodiesel production (40%), olives (29%) and other oil crops such as sunflower (28%). Soybean production only accounts for 2% of the harvested area. In India, the area for oil crops production is dominated by soybean (35%), rapeseed (22%), groundnut (18%) and other crops such as sesam seed and sunflower seed (24%).

Vegetables (including spices) and fruits account for 9% of the crops area in EU-27, and 7% in India. The top 3 of fruits, on area base, are grapes (56%), citrus (10%) and apples (9%) for EU-27 and mangos (37%), bananas (13%) and citrus (12%) for India. The top 3 of vegetables (including melons) on area base are tomatoes (12%), onions (8%) and green peas (8%) for EU-27, and onions (15%), tomatoes (11%) and egg plants (9%) for India.

Fiber plants, mostly for cotton production, take a significant parts of the crops area in India (7%), but is negligible in Europe (<1%). In Europe, hemp and flax have renewed interest.

Starchy roots, dominated by potato production, accounts for 1-2% of the crops area, both in EU-27 and India. Sugar crops, dominated by sugar beet in Europe and sugar cane in India, takes 2-3% of the crops area, both in EU-27 and India.

Other crops, like treenuts, represent a smaller fractions of the harvested agricultural area.

Direct agricultural biomass production (excluding forage)

Figure 4 shows the agricultural production that is achieved for both Europe and India. The production corresponds to the cultivation areas summarized in Figure 3. The values are given in Mton and correspond to the (fresh) weight of the commodity of interest that is used for further processing/use. These are for instance wheat grains before milling, sugar and oil seeds before pressing, fresh olives, vegetables and fruits. Rice, as an exception is reported as milled equivalent. Harvesting residues, like for instance straw or horticulture residues are not included.

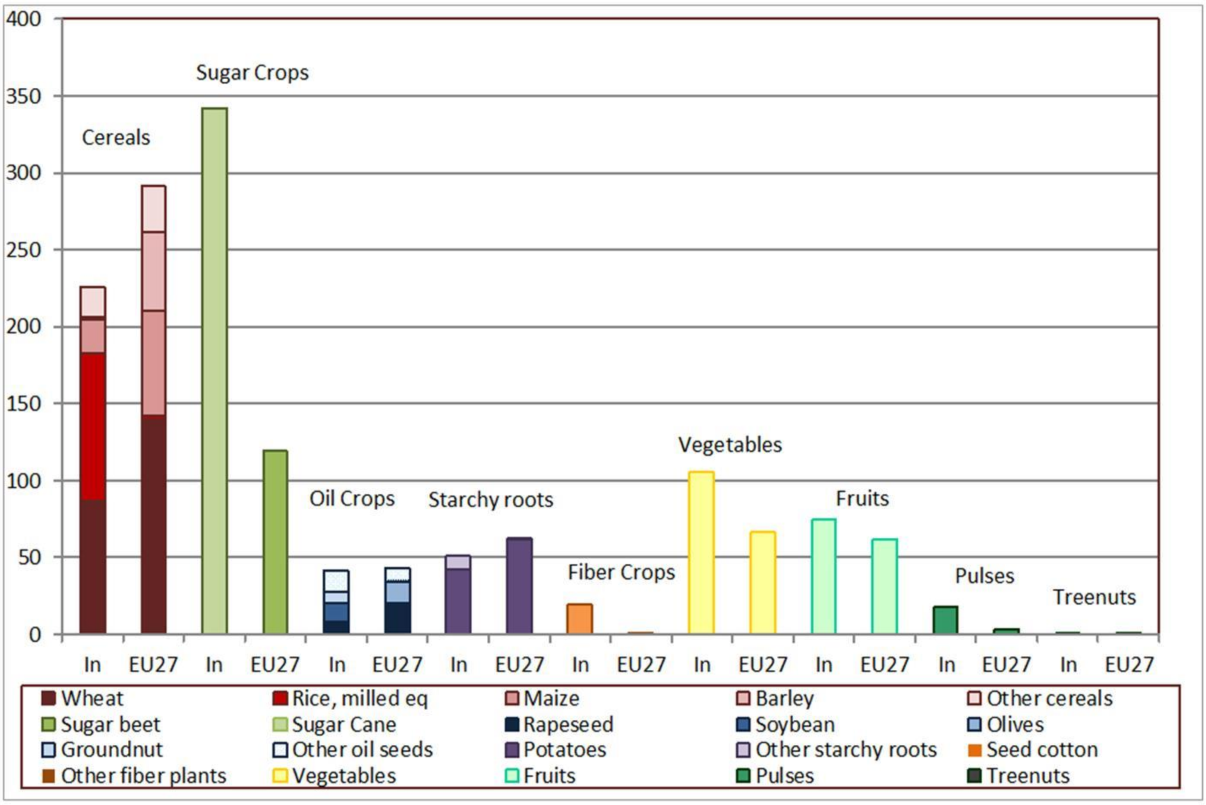


Figure 4: Comparison of the productions of the different crops.[12] The productions are given as the amount of the commodity (seed, vegetable...) of interest (in Mton). The agricultural by-products, like straw are not included.

When comparing the acreages of Figure 3 with the corresponding productions as displayed in Figure 4, some differences can be noted. Whereas food grains crops dominate agricultural land use in both Europe and India, the associated production of grains is still large, but less dominant. The class of food grains represents 45% of the crops production in Europe and only 28% in India, both mostly composed of cereals. The cereals production is dominated by rice (42%) and wheat (38%) in India, and by wheat (48%), maize (23%) and barley (18%) in EU-27. Due to differences in yields, the wheat production is larger in Europe than in India, despite the similar crop areas harvested. The yield of wheat ranges in the EU between roughly 2-4 ton/ha (south and east EU-27) to 7-9 ton/ha in west EU-27, with an average of 5.3 ton/ha. Also in India, strong regional differences exist, with yields ranging from 1-2 ton/ha to 3-5 ton/ha in the Gangetic plain, with an average of 3.0 ton/ha. In EU-27, rice is cultivated mostly in the south of the EU with an average yield of 4.3 ton/ha (milled equivalent). India, has a significant rice production in the North-East, East, and South-East of the country. The production yields vary between 1.6 and 3.5 ton/h, with an average of 2.2 ton/h.

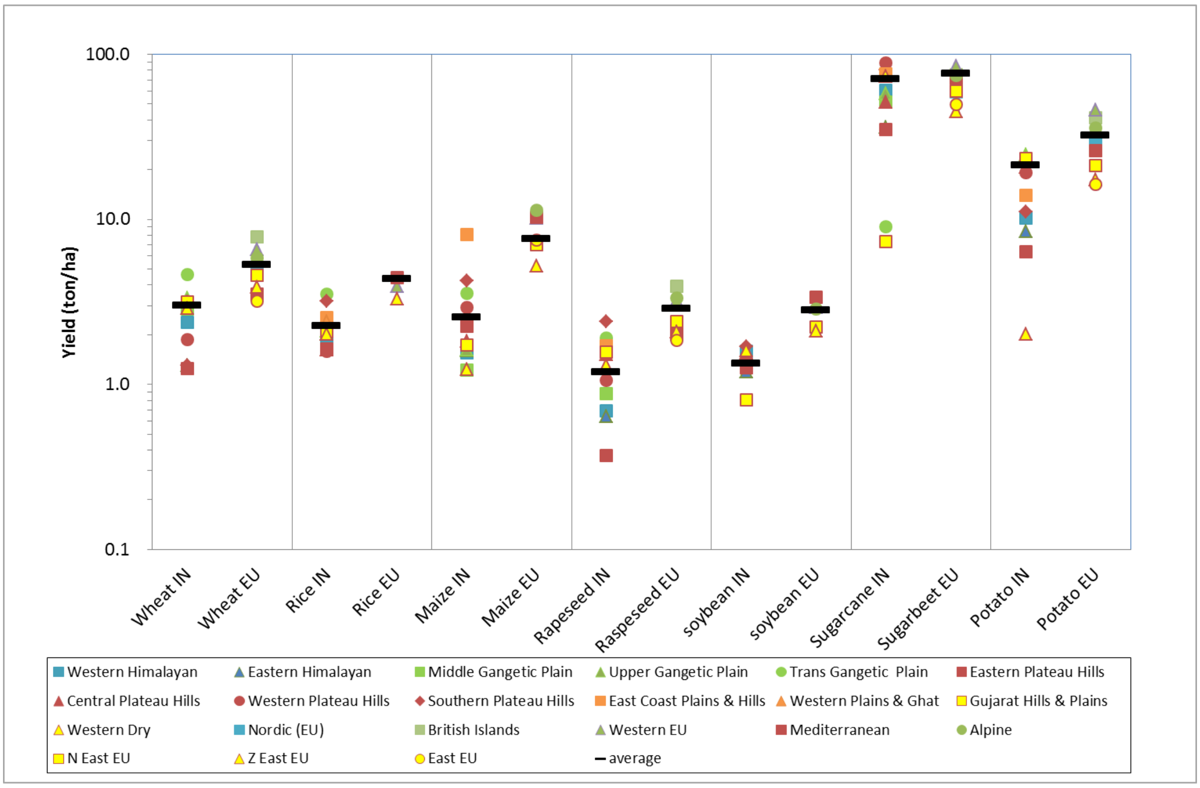


Figure 5: Regional variability of the production yields of a selection of crops, having (partial) industrial or energetic end-use. The EU-27 data are based on FAO statistics (2011)[12], by selecting the EU-27 countries belonging to the climatic zones as defined in the work of Olesen and Bindi.[13] The data of India are based on the crop production statistic Information System of India (2010-2011).[14]

Sugar crops, despite their small cultivation area, represent 39% of crop production in India, and 18% in Europe. Sugar cane, in India, has an average yield of 70.1 ton/ha (7.1 ton sugar/ha)[b15], and is mostly cultivated in the Upper Gangetic plain and the Eastern plateau and Hills region. Sugar beet, in Europe, has an average yield of 76.0 ton/ha (10.4 sugar/ha)[16], and is mostly grown in Western EU.

Oil crops, being the second most important after food grains as far as land use is concerned, accounts for 5% (India), respectively 7% of the production (on seeds basis). In Europe oil crops are dominated by rapeseed (45%) and olives (32%), in India by soybean (29%), rapeseed (20%) and groundnut (17%). In the EU, rapeseed is mostly cultivated in Western EU (3.2 ton/ha), Olives mostly in the Mediterranean area. In India, soybean is mostly cultivated in the western Himalayan region (1.6 ton/ha), rapeseed in North-West (average yield of 1.5 ton/ha).

Starchy roots, mostly potatoes, accounts also for a significant part of the crops production, being 6% in India and 10% in the EU. Potato production is concentrated in the Upper Gangetic Plain in India (24.7 ton/ha), and in Western and North-eastern Europe (EU-27 average 31.9 ton/ha).

Fiber production, and more specifically seed cotton for the production of cotton lint, represents 2% of the production in India, and is a minority crop in the EU.

Direct biomass production from agriculture dedicated to non-food/feed applications and associated land use

Very little systematic information is available on all current non-food/feed utilization of biomass, both in Europe and India. As first generation resources, mostly sugar, starch and vegetable oils are used for the production of biobased chemicals/materials and/or biofuels. In addition, to some extent energy crops and a broad range of by-products or waste streams are used for renewable energy production. In India, very few first generation resources are consumed for non-food products, with the exception of fibers. Some side-products are used, such as molasses from sugar cane processing for the production of bioethanol.

In Europe, sugar trade is regulated through quota by the Common Agricultural Policy (CAP). In 2010-2011, in total 15,8 Mton of sugar was produced, resulting in an out-of-quotum of 2.7 Mton (+0.05 Mton of isoglucose), of which 2.4 Mton/y was available on the markets. Of this 0.65 Mton was used for industrial use, and 0.87 Mton for bioethanol. In 2011-2012, with an out-of-quotum of 4.9 Mton/y, the usage for bioethanol was higher and amounted 1.4 Mton.[17] This corresponds to roughly 13.8 Mton of sugar beets, of which 9.4 Mton for bioethanol, and 4.4 Mton for other industrial use. The total crops area for industrial use, including biofuel, is estimated at 0.2 Mha. After 2017 the sugar production in Europe is expected to raise strongly (no quota anymore) and will boost the bio-industry.

According to the European Starch Industry (2012), 7.7 Mton of maize, 7.8 Mton of wheat and 7.5 Mton of potatoes are used for starch production, resulting in roughly 10 Mton of starch, composed of 47% maize, 38% of wheat, and 15% of potato starch. In Europe, starch finds significant industrial outlets in paper making (28%), pharma and chemicals (5%) and other non-food applications (4%). It can be derived that roughly 1.0 Mha is dedicated to industrial use (mostly for paper making).

Wheat, Maize and some minor fractions of Barley and Rye fractions are also used for bioethanol production. For 2012, it was estimated that 4.2 Mton of wheat and 4.2 Mton of Maize and ~0.8 Mton of other grains were used.[18] This corresponds to roughly 1.6 Mha.

[b] Calculated from the average recovery yield of 10.17% reported.

Some oils have significant outlets as oleochemicals and biofuels (biodiesel). It is estimated that in EU roughly 11 Mton is used for domestic industrial consumption (2011-2012), of which 6 Mton rapeseed oil, 2.4 Mton palm oil, 0.9 Mton soy oil, and 0.2 Mton sunflower oil.[19] The feedstocks rapeseed and sunflowerseed are mostly grown within the EU (import and export of seeds and oils are more or less balancing each other), whereas the soy bean (mostly) and palm oil (fully) are imported. The locally produced oilcrops dedicated to industrial application, i.e. rapeseed and sunflowerseed, are mostly used for the production of biodiesel (6.2 Mton rapeseed and 0.15 Mton sunflower oil) an their corresponding crops area is estimated at 5.5 Mha.

In addition, in some regions of Europe, some crops like maize, sugar beet, wheat, are part of the feedstock mixture used for biogas production, together with manure, and some industrial and agricultural by-products and biowastes. Germany, with many biogas units at farm sites, is accounting for 80% of the overall energy crops used for biogas production in the EU. It is estimated that roughly 1.1 Mha is dedicated to the production of these crops, mostly maize.[20]

Finally also perennial or short rotation woody biomass energy are grown for electricity and heat production.[21] The area is small and estimated between 0.08 and 0.09 Mha (2011).

In India, few information is available on the land use for the production of biobased chemicals/materials and/or biofuels.

As mentioned in section 3, fiber production, mostly seed cotton for the production of cotton lint, represents 8% of the gross cropped area, with an area of 13.2 Mha (2011).

Oils, as produced from oil crops, have currently limited industrial outlet in oleochemicals and biofuels. From the 18.1 Mton oils domestically consumed, 17.3 Mton is estimated to have food use (2012-2013).[22] It is estimated that currently only ~0.05 Mton of oils are used for the production of biodiesel (2013). In addition, used cooking oils and animal fats are also used as feedstock, as discussed in the next section. The cultivation area of the associated oil production is still very low. An estimated 0.5 Mha of wasteland has been covered under *Jatropha* cultivation (2010). However, biodiesel production from *Jatropha* remains insignificant.[22]

In India, sugar is only used for food and feed applications. Virtually no centrifugal sugar is consumed for alcohol, feed or other non-human consumption. Gur, mostly consumed in rural areas, is used to some extend as feed as well. The side products of sugar processing, such as molasses and bagasse, are used for bioethanol production and bioenergy. These will be considered in the next section.

In India it is estimated that around 1.56 Mton starch and derivatives were manufactured in 2012.[23] While maize is the main raw material, to a much smaller extent, tapioca, potato and rice are also utilised for the manufacture of starch. Key products from these raw materials include native starch, modified starches and sweeteners including syrups and polyols. The annual maize production in India is around 21.6 Mton, whereas that of tapioca is 5.4 Mton and that of rice is 108 Mton (2011-12). A very small proportion of the total yield of maize is used for starch manufacture (around 9 %), as it is directly utilised for human consumption (33%), poultry feed (46.5%), animal feed (11%) and as corn flour, to serve as a texturizing agent in many food and beverage matrices (0.5%).[24] While tapioca contributes about 2.5 % for starch manufacture.[23] In India, the largest consumer of starch is textile industry followed by paper, pharma and food industry.

Indirect biomass production from agriculture dedicated to non-food/feed applications

Besides the primary resources, also side products and wastes from the agricultural production or processing are used for bioenergy. No real land use is attributed, as these products are obtained as side products from the agricultural activity or production. For Europe, examples are animal fats (0.4 MTon, 2012) and recycled oils (1.2 Mton, 2012) for biodiesel production, manure (88 Mton or 6.4% of total manure production[25]), sludges and food wastes for biogas production, and processing by-products such as olive pomace or meals from animal-by products for energetic purposes. Some information is available, however only on a fragmentary basis, and often also depending on whether the by-product of interest is classified as waste. Furthermore, as is the case for instance for olive pomace, moisture content and composition of the side stream may differ depending on the exact technology applied, making a comparison on mass basis difficult.

For *Europe*, NREAP gives an indication of the total energy that is currently produced out of agricultural by-products, which include straw, manure, animal fat, meat and bone meal, cake by-products, fruit biomass, fishery by-products and clippings from vines, olives and fruit trees. The total amount of energy created out of these agricultural side streams is estimated to be 6.2 MTOE, and represents roughly 7% of the total primary renewable energy (2006)[c]. The lead is taken by Spain, having significant valorisations of cakes, mostly olive pomace, towards bioenergy.

In *India*, approximately 2.2 Mliters of Bioethanol are produced using 9 Mton of molasses. This includes 0.72 Mliters for industrial use and 0.4 Mliter for fuel. This implies that ~4.7 Mton of molasses is used for bioethanol that has chemicals or biofuels end-use. The remaining is used for the production of potable liquor.[26] Roughly 10% of the molasses are also used for feed.

Additionally also 56 kTon of used cooking oils, and 6 kTon animal fats are used for biodiesel production (2013).[22]

The sugar industry has been traditionally been practising cogeneration with bagasse. With the advancement in technology and the modernisation of new and existing sugar mills, also a surplus power generation through the cogeneration of bagasse is achieved. The current installed capacity of bagasse cogeneration (on-grid) is estimated at 2337 MW (2013). In addition, additional capacity has been installed for the co-generation of by-products from other industries, such as pulps and textiles. The installed capacity (off-grid) amounts 475 MW (2013).[27]

In addition power is also produced from biomass through mostly thermal processes such as combustion. These power plants are based on agricultural wastes, and the installed capacity (on-grid) amounts 1265 MW (2013). The usage of their full capacity is hampered by the non-availability and volatility in cost of reliable and affordable feedstock, as it faces competition from other applications in breweries, briquetting, paper industry, cattle fodder and rural households.[28]

Finally also (small scale) biomass gasifiers have been installed, both rural as well as industrial, with a total installed capacity of 160 MW (2013). Power for such a small capacity can be generated from animal waste, forest waste, agro-food processing industries and kitchen waste. The most actual information, as provided by the Ministry of New and Renewable Energy, is shown in Table 4.

[c] Excluding 3 MS: EE, LV and SI.

Table 4*:* Current Bioenergy power generation in India.[29].

No.	Sector	Total Deployment (2012-13)	Cummulative Capacities (till 31.07.2013)	Total target (at end of 12th five year plan)	Estimated Potential
Grid Interactive Power (Capacities in MW)					
1.	Biomass Power	113.50	1263.80	1525	18,000
2.	Baggasse Cogeneration	315.70	2337.43	3216	10,000
3.	Waste to Power (Urban& Industrial)	6.40	96.08	324	2,700
Off Grid / Captive Power (Capacities in MW_{EQ})					
4.	Waste to Energy (Urban & Industrial)	13.82	115.57	NA	NA
5.	Biomass Cogeneration (non-bagasse)	60.59	486.84	NA	NA
6.	Biomass Gasifiers			NA	NA
	(Rural)	0.672	18.79	NA	NA
	(Industrial)	6.02	140.10	NA	NA
	Biogas based Energy System	0.65	0.65		
7.	Family Biogas Plants (in 000')	77	4623	5600	12,000

NA: Not Available
*Includes 1932 MW from private sector sugar mills while additional capacity from cooperative sector likely to be commissioned by August 2012

3.2.3 Agro-environmental factors affecting current agricultural biomass production

Soil

Soil is a critical component on earth not only for sufficient food production, but also for maintaining the sustainable global environmental conditions. Due to its slow rate of formation, soil loss is not recoverable, which implies that soil must be regarded as a non-renewable resource. Several threats can lead to the degradation and irreversible loss of soil. The degradation contributes to food shortages, higher commodity prices, desertification and ecosystem destruction. It is largely induced by the unsustainable use of land, like for instance loss of organic carbon, erosion, nutritional imbalance, compaction, salinization, water-logging, decline in soil bio-diversity, urbanization and pollution. In *India*, it was estimated that 146.8 Mha of the land is suffering from various kinds of land degradation (see Table 5).

However, the estimates of various sources vary, indicating that more research is needed for aligning the approaches in the definition of the degraded soils and the criteria for delineation. Also in *Europe* significant areas are affected (see Table 5 for rough estimates), with water erosion and chemical degradation as the most dominant causes of soil degradation.

Table 5: Estimates of the area that is affected by soil degradation for Europe and India.

Threats	**India**[30]	**Europe, excl. Russia**[8,31]
Erosion		
Water erosion	94 Mha >50% of the area in CG, JH, MP, UP, UK & NE-states	115 Mha e.g. Mediterranean
Wind erosion	10 Mha	42 Mha e.g. North Europe
Chemical degradation		
Organic matter losses		3.2 Mha 45%: low to very low organic content e.g. south-EU, but also in regions in FR, D, UK, and B
Salinization	5.9 Mha (4.1 Mha of agricultural land)	3.8 Mha Naturally saline: ES, HU, EL, BG Artificially saline: I, ES, HU, EL, P, SK, RO
Acidification	16 Mha	Significantly reduced since 1980
Pesticides		180 Mha
Nitrates and Phosphates		170 Mha 15% of EU25 has N>40 kg/ha
Physical degradation		
Compaction		33 Mha 1/3 of sub soils are threatened
Water logging	14.3 Mha	0.8 Mha

Water

In *Europe*, agriculture receives 24% of the abstracted water.[32] Irrigation as a part of intensive agriculture, including horticulture, has led to other problems, such as soil salinization. In southern Europe, agriculture accounts for 60-80% of the abstracted water. Agricultural use of water has increased significantly over the last two decades, but appears currently to be stable at a high level. The agricultural sector generates a significant pressure on both surface and ground waters in terms of quantity as well as quality. More efforts are needed to reduce the impact of agriculture on Europe's water resources. In 2010, in 34% of the monitoring stations still an increase in the nitrate content of groundwater was observed, with 15% of the monitoring stations exceeding the threshold of 50 mg/l.[33] For fresh surface water, on the other hand, the pressure from agriculture has decreased in many MS.

In *India*, agriculture receives 90% of the total water withdrawal.[34] Several parts of India are already facing water shortages and the problem will become acute by 2050 (17% of the population will be under absolute water scarcity) when nearly all the estimated available water will be used as a result of increasing population and food demand. India currently has an overall irrigation potential of 140 Mha, out of which only about 109 Mha have been created, and around 80 Mha utilized.[35] Groundwater irrigation, which is a bigger source of irrigation today in India, suffers from over-exploitation in most of the states, particularly in the north-west where the water table is depleting drastically. The Gross Irrigated area relative to the Gross Cropped area has increased from 34% in 1990-91 to 45.3% in 2008-09. However, there are wide variations in irrigation coverage has been seen across states (Figure 6A) and crops (Figure 6B). Thus, diversified crop selection as per the state geographical and agronomical conditions can improve the agricultural production..

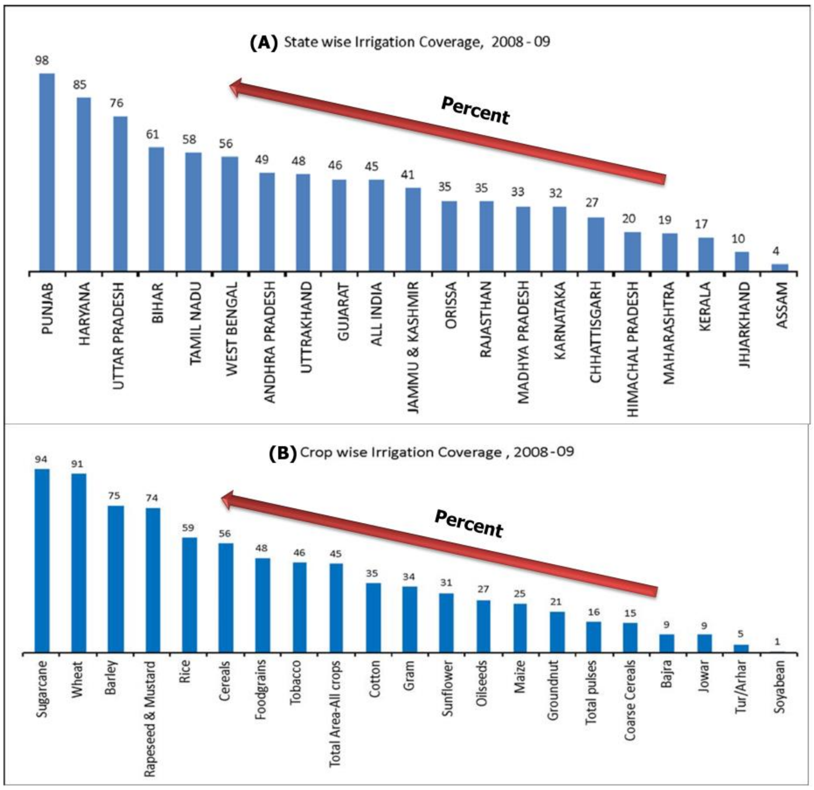


Figure 6: State-wise irrigation coverage (A) and crop-wise irrigation coverage (B) reported in India during 2008-09.[35]

<u>Fertilizers</u>

Fertilizers form another important input in agricultural growth. With appropriate nutrient application rates, the yield of biomass production can significantly be enhanced.

In *EU-27*, fertilizer application declined since late 1980s. The fluctuations of the last decade are shown in Figure 7. Over the last 3 growing seasons, on average 10.2 MTon nitrogen-based fertilizers (all), 2.2 MTon phosphate (P_2O_5) and 2.4 MTon potash (K_2O) were applied annually to 134 Mha of farmland.[d,36] This implies that on average 110 kg/ha mineral fertilizers are used, of which 76% for the supply of nitrogen (see Figure 8). Today, Europe has the highest efficiency of nitrogen use in crop production worldwide. In EU-27 nitrate-based fertilizers are the most preferred product (47%), in contrast to the worldwide consumption where urea is dominating (56%).[37] As compared to urea, nitrate-based fertilizers have a higher agronomical efficiency, result in lower ammonia volatile losses a have a lower carbon footprint. Nevertheless, there is still a large potential for the improvements in the nutrient use as on average only 50% of the nitrogen applied in the form of fertilizers is actually taken up by the crop.

In addition to mineral fertilizers, in EU-27 also organic fertilizers from slurry, manure and to a lesser extent sewage sludge are used as a source of nitrogen and phosphorus. Nevertheless, they contribute to a greater overall nitrogen “pressure” on EU-15 soils, partially due to the uneven spatial distribution. In the EU-15 an estimated extra nitrogen input of 7.6 MTon from animal husbandry is annually spread on the agricultural soils. Added to the mineral fertilisers used, this increased the diffuse nitrogen “pressure” to approximately 16.5 Mt in 2003. For the EU-27 similar but less pronounced trends were noticed. For 15 out of 22 MS[e], manure is the main source of phosphorus. This is especially apparent in MS with a high density of animal farms. Moreover, 18[f] out of the 22 MS have a phosphorus surplus which is not always appropriately managed in the MS. Reducing phosphorus inputs in those regions where soils are saturated would not only decrease problems of eutrophication, but also reduce cadmium inputs from mineral phosphate fertilisers.

In *India* the overall consumption of fertilizer has significantly increased from 70 kg/ha (1991-92) to 144 kg/ha (2010-11). The N, P, K balance (see Figure 8), is seriously distorted particularly in areas with a high fertilizer use e.g. northwest. It is apparent that an integrated nutrient management approach is required to enable a balanced use of fertilizers for optimum results. Also, the setting up of adequate capacity for soil testing needs to be continued. Thus, the dependence on chemical fertilizers for future agricultural growth would mean further loss in soil quality, possibilities of water contamination and unsustainable burden on the fiscal system.

The organic plant nutrients and biofertilizers offer a promise to balance many of the shortcomings of the conventionally applied minerals.[38] The major sources of organic plant nutrients in India are farmyard manure, rural and urban compost, sewage sludge, press mud, green manures, crop residues, forest litter, industrial waste and by-products. To attain production targets, the Government of India implemented a central sector scheme called National Project on Development and use of Biofertilizers during the Ninth Plan for the production, distribution and promotion of biofertilizers. The number of bio-fertilizers such as blue green algae and azolla are used extensively in India to meet the nitrogen demand of the crop. Small quantities of powdered neem cake are also used. These organic nitrogen supplements unlike the fertilizer nitrogen do not suffer any loss in the fields. Phosphorous-solubilising and mobilising organisms such as *Phosphobacterium* and *Vesicular arbuscular*

[d] Roughly 48 Mha of farm land, mostly grassland, remains unfertilized.
[e] No data available for Cyprus, Luxembourg, Bulgaria, Romania and Malta
[f] All 22 MS, with the exception of the UK and the 3 Baltic States.

mycorrhizae (VAM) are quite helpful in meeting the phosphorus demand of the crop. Potassium for the crops can be supplied by using potassium rich organic amendments such as burnt rice, rice straw composted using *Tricoderna harzianum*.

The total biofertilizer production in India was 40.3 kTon in 2010-11[39], with the highest contributions from Maharashtra and Uttar Pradesh (~8.7 kTon). Based on the gross cropped area in India (~190 Mha) and recommended doses of bio-fertilizers, the potential demand is estimated to be 627 000 MTon.[40] This demand can be further segregated into different categories of bio-fertilizer, including *Azotobactor,* Blue Green Algae and Phosphate Solubilizer as the most important ones. New units and significant capacity built up has taken place over the years, however, the production is limited to actual demand. The current trends indicate that there is a steady increase in the demand in the Southern states except Andhra Pradesh, Western States and Madhya Pradesh and Rajasthan. Currently the attention given both in terms of policy framework and institutional dynamics towards organic agriculture is only marginal. Therefore, understanding of the nature of market, customer's aspirations and providing appropriate solution to them through well-defined communication strategies' is utmost needed.

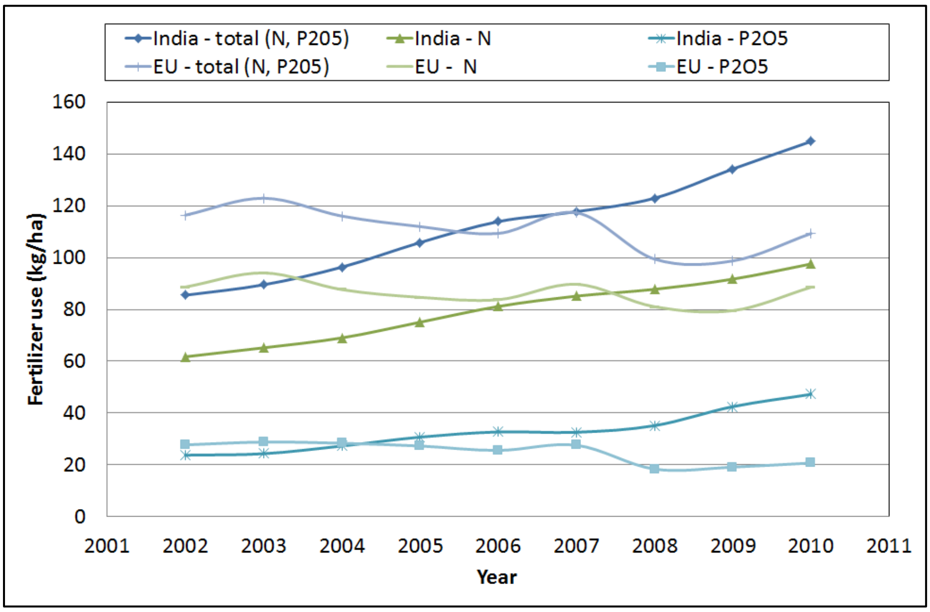


Figure 7: Evolution of the amount of fertilizer (N, P_2O_5) applied per ha (arable and permanent crops land).[41]

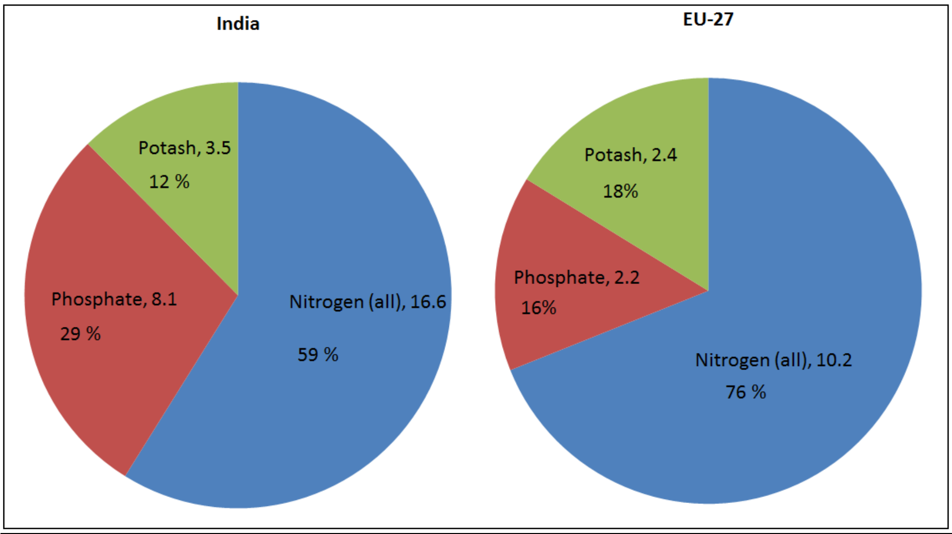


Figure 8: total amounts (in Mton) and relative importance (in %) of the different types of mineral fertilizes.

<u>Pesticide & Plant Protection (PPPs)</u>

Europe: In EU[g], approximately 314 kton of PPP (active substance) were used in 2010, of which 41% bactericides and fungicides, 34% herbicides, 12% insecticides, 3% plant growing regulators and 10% other products. The top users were Italy (22%), France (20%) and Germany (13%) and Spain (12%).[42] The use of PPPs per hectare of agricultural land for crop protection is much higher in the western than in the eastern MS. Irrigated farming generally relies on high to very high doses of pesticides per hectare, whereas no PPP are used in extensive grazing systems. Data provided by the European Crop Protection Association for EU-25 showed that in 2003 the average dosage rate for crop protection was on average 2.1 kg active substance (AS) per ha. The dosing was shown to be strongly crop specific, with the arable crops having a dosing of 1.1 kg AS/ha, and the fruit and vegetables 15 kg AS/ha.[43] The total amount of PPP declined continuously from 1999 until 2003, attributed to the EU-15 MS while the consumption of PPP in the new MS slightly increased during that period. The replacement of products used at high dosage rates by substances active at very low dosages is probably the main reason for the overall decrease; however, new approaches to agricultural management, namely the increase in organic farming in north-western Europe and the use of integrated crop management in many pesticide-intensive farming systems also play a role. By 2014, minimum requirements for integrated pest management will become mandatory for all farmers in the EU, in accordance with the Framework Directive on the sustainable use of pesticides.

India: The consumption of PPP in India was approximately 41 kton (active substance) in 2010, of which 32% bactericides and fungicides, 16% herbicides, 51% insecticides and less than 1% plant growing regulators.[42] India's consumption of pesticides is only 2 percent of the total world consumption.[44] The dosing rate was on average 381 g/ha (technical grade), which is low as compared to the world average of 500 g/ha.[35] The low consumption can be

[g] 21 MS, Excluding Belgium, Bulgaria, Cyprus, Luxembourg, Malta and Greece.

attributed to the existence of fragmented land holdings, dependence on monsoons, insufficient awareness among farmers, etc. Only 25-30 percent of the total cultivated area in the country is under pesticide cover. In response to major pest attacks in recent years, some states have implemented intensive pest surveillance and management systems for major crops vulnerable to pests and diseases under Rashtriya Krishi Vikas Yojana, e.g., Maharashtra in 2009 (for soybean and pulses) and Orissa in 2010 (for rice). The new strategy has proved to be effective and has been advocated for other States by the National Centre for Integrated Pest Management of ICAR. To monitor pesticide residues in agricultural commodities for consumption, a central sector scheme entitled “Monitoring of Pesticide Residues at National Level” in food commodities and environmental samples has been in operation since October, 2006 with the participation of 21 laboratories functioning under the following: the Ministry of Agriculture, Indian Council of Agricultural Research, Ministry of Health and Family Welfare, Ministry of Environment and Forests, Council of Scientific and Industrial Research, Ministry of Chemicals and Fertilizer, Ministry of Commerce & Industry and State Agricultural Universities across the country. Further, the government is promoting Integrated Pest Management (IPM) as the main plank of a plant protection strategy for safe and judicious use of pesticides. IPM involves use of cultural, mechanical, biological methods and the use of pesticides as a last resort for controlling insects-pests, diseases and weeds.

3.2.4 Current biomass production from forests

<u>Characteristics of the forests</u>

The forests of India and the EU-27 differ quite significantly in their characteristics, as summarized in Table 6. The forest area of EU-27 is larger, on average more dense, and relatively more populated with coniferous species. The EU-27 forests are more dedicated to production, making the forestry an important source of renewable biomass for Europe.

The Indian forest on the other hand, has still a significant amount of natural (primary) forest and contains large protected areas.

Table 6: Comparison of the characteristics of the forests in India and EU-27. The data are based on various forest reports from Eurostat, the ministry of environment and forests in India.[45,46,47]

Forests characteristics	India	EU-27
Land use		
Forest area	68.4 Mha	156.9 Mha
Increase 2005-2010	0.21%	0.32%
Other wooded land Tree out of forest	3.3 Mha 9.1 Mha	20.9 Mha
Properties		
Broadleaved/coniferous	90%/10%	38%/62%

Density	80 m^3/ha	153 m^3/ha
Classification		
Primary	23%	3%[h]
Other naturally regenerated	62%	69%[h]
Planted	15%	28%[h]
Ownership		
Private/public	14%/86%	60%/40%
Primary function		
Production	25%	58%
Protection soil/water	16%	9%
Conservation biodiversity	29%	11%
Social services	0%	2%
Multiple use	30%	20%

Besides being an important source of renewable resources, the *EU-27* forests sequester increasing amounts of carbon in tree biomass. Each year about 430 MTon of CO_2 (2010)[48] , or around 10% of total greenhouse gas emissions, are removed from the atmosphere by photosynthesis and tree biomass growth. In the EU-27, the total carbon stock in living forest biomass amounts to ~9900 MTon.[48] There are 178 Mha of forests and other wooded land in the EU, representing about 42% of its total land area. The largest proportion of forests and other wooded land relative to terrestrial are is found in Finland (77%) and Sweden (75%), followed by Spain (57%), Italy (37%), Germany (32%) and France (31%). Together, these six MS account for more than two thirds of the total forest area in the EU. About 3% is classified as primary forest, or undisturbed by men, 69 % as other naturally regenerated, and 28% as planted.[47] In total 20.4 Mha (13%) of the EU-27's forest area is protected, of which 17.4 Mha (11%) for conservation of biodiversity. Contrary to what is happening in many other parts of the world, the area covered by forests and other wooded land in the EU-27 has increased over the past 20 years (1990 to 2010) in total by 5.3%, or ~9 Mha, equivalent to an average increase of 0.3% per annum, as a result of afforestation programs and due to natural regeneration on marginal lands. Largest increases in the range of 10-25% took place in the United Kingdom, Lithuania, Bulgaria, Italy, Latvia and Hungary, while Ireland even recorded a 64% increase. Ecologically, the EU's forests belong to many different biogeographically regions and have adapted to a variety of natural conditions, ranging from bogs to steppes and from lowland to alpine forests. Socioeconomically, they vary from small family holdings to state forests or large estates owned by companies, many as part of industrial wood supply chains. Roughly 60% of the EU-27's wooded land is privately owned.

In *India*, the carbon stock in living forest biomass is estimated to be ~2800 Mton (2010)[47]..The total carbon stock, including soil and dead biomass, is around 6700 MTon[46]. According to the Indian State of Forest Report, India has 69 Mha of forest and 9 Mha of tree

h. Excluding Austria and Cyprus.

cover out of forests. When excluding geographical areas above an altitude of 4000 m, the forest and tree cover amounts 25% of the geographical area. Out of the total forest area, 28.8 Mha is open, 32.1 Mha is moderately dense, and 8.4 Mha is very dense forest land. In addition there is also 0.4 Mha of scrub land, i.e. degraded forest with a tree cover of canopy density less than 10%.

The North eastern region of India is endowed with very rich forest resources. The region, which constitutes of only 8% of the geographical area of the country, accounts for almost one-fourth of the total Indian forest area. Because of the biodiversity richness, the region has been identified as one of the 18 biodiversity hot spots of the world. It is made up of 8 states having a forest coverage of 17,3 Mha accounting for 66% of its geographical area in comparison with the national forest cover of 21% and more specifically have the following percentage of the forest to their respective geographical area Mizoram (91%), Arunachal Pradesh (81%), Nagaland (80%), Meghalaya and Manipur (77%), Tripura (76%), Sikkim (47%), and Assam (35%).

The states with the largest forest areas (relative to the total Indian forest area) are found in the large central states. These states, covering about 40% of the total Indian forest area, comprises Madhya Pradesh (11%), Chhattisgarh (8%) and Maharashtra, Orissa and Andhra Pradesh (7%), .

A significant part of the Indian forest is classified by the Indian Forest Act as reserved (55%) and belongs to the most restricted category having full protection, whereby no activities are not allowed unless permitted, included the use by local people. In addition, part of the forest is classified as protected (28%), whereby the state retains power to issue rules regarding the use, but in absence thereof most practices are allowed. It is estimated that 29% or 19.8 Mha is designated to the conservation of biodiversity, and 16% for the protection of soil and water. Approximately 30% has multiple uses and 25% or 17.4 Mha, is designated for the production of wood fiber and bioenergy.[49]

In India, many different forest types exists, of which the tropical dry deciduous (42%), the tropical moist deciduous (20%) and the tropical semi-evergreen forest (14%) are the most important ones. About 62 % of the forests is classified as semi-natural and 23% as natural and undisturbed by man. The remaining 15 % concerns planted forest.[49]

<u>Direct and indirect forestry biomass production</u>

Whereas in EU-27, forestry is a significant source of biomass for both materials as well as bioenergy production, most of the wood in India, i.e. industrial roundwood and fuelwood, comes from outside the forests. The characteristics of wood production and their residues is shown in Table 7, Since it is difficult to distinguish in India between the direct and the indirect sources of biomass from forestry, all categories are treated together.

Table 7: Comparison of the biomass production from the forests and the TOF in India and EU-27. The data of several sources are given. ob=overbark; ub=underbark

	India	EU-27
Growing stock		
In forest	4500 Mm^3ob	24900 Mm^3ob
In FAWS		21800 Mm^3ob
In TOF	1500 Mm^3ob	
Net actual increment available for wood supply		768 Mm^3 ob
Primary production roundwood[47] (2005)		
Industrial Roundwood[i]	46.0 Mm^3 ob	382.2 Mm^3 ob
% from forest	~6	~100
Fuel wood[i]	260.8 Mm^3 ob	98.0 Mm3 ob
% from forest	~20	~91
Primary production roundwood[50] (2012)		
Industrial Roundwood	23.2 Mm^3 ub	336.7 Mm^3 ub
% Coniferous/non-coniferous	1/99	77/23
Fuel wood	308.2 Mm^3 ub	93.1 Mm^3 ub
% Coniferous/non-coniferous	3/97	28/72
Other wood resources[51] (2010)		
Forest residues		39.2 Mm^3
Landscape care		33.4 Mm^3
Bark		51.1 Mm^3
Other industrial wood resources		
Total Industrial residues (2010)[51]		103.7 Mm^3
Solid biofuels in Sawmill industry (2008)[52]		39.8 Mm^3
Solid biofuels in mechanical pulp industry (2008)[52]		5.5 Mm^3
Solid biofuels in Chemical pulp industry (2008)[52]		10.4 Mm^3
Black liquor (2008)[52]		69.7 Mm^3
Solid biofuels in plywood industry (2008)[52]		2 Mm^3

i. Excluding romania, with estimated 11.5 Mm3 ub (industrial, 2005) and 3.0 Mm3 ub (fuelwood, 2005)

Approximately 133 million hectares of the *EU-27's* forests or 32% of the EU's land area are currently available for wood supply (FAWS). The total growing stock is estimated at 21.8 billion m^3 overbark (ob) (or 163.3 m^3 ob/ha) in the forest area available for wood supply (2010).[45] The countries with the greatest total growing stock are Germany (3.5 billion m^3ob, 328 m^3/ha), Sweden (2.7 billion m^3 ob, 129 m^3/ha), France (2.5 billion m^3 ob, 162 m^3/ha), Poland and Finland with both around 2 billion m^3 ob The net annual increment in growing stock in the forests available for wood supply is estimated at 768 million m^3 ob (2010).

The EU's forests are highly productive in terms of biomass supply: roundwood production in the EU-27 in 2012 was 429.8 Mm^3 underbark (ub). This included 336.7 million m^3 industrial roundwood, mostly coniferous (77%), and 93.1 million m^3 fuelwood, mostly non-coniferous (72%). This implies that 79% of the roundwood production has a primary industrial designation (sawn & panel industry, pulp & paper industry…), 21% finds direct application as bioenergy. Among the MS, Sweden produced the most roundwood (65.1 million m^3) in 2012, followed by Germany, France and Finland (each producing between 54 million and 56 million m^3). France is by far the country with the highest amount of roundwood used for energy (see Figure 9), with roughly 26% originating from outside the forests.

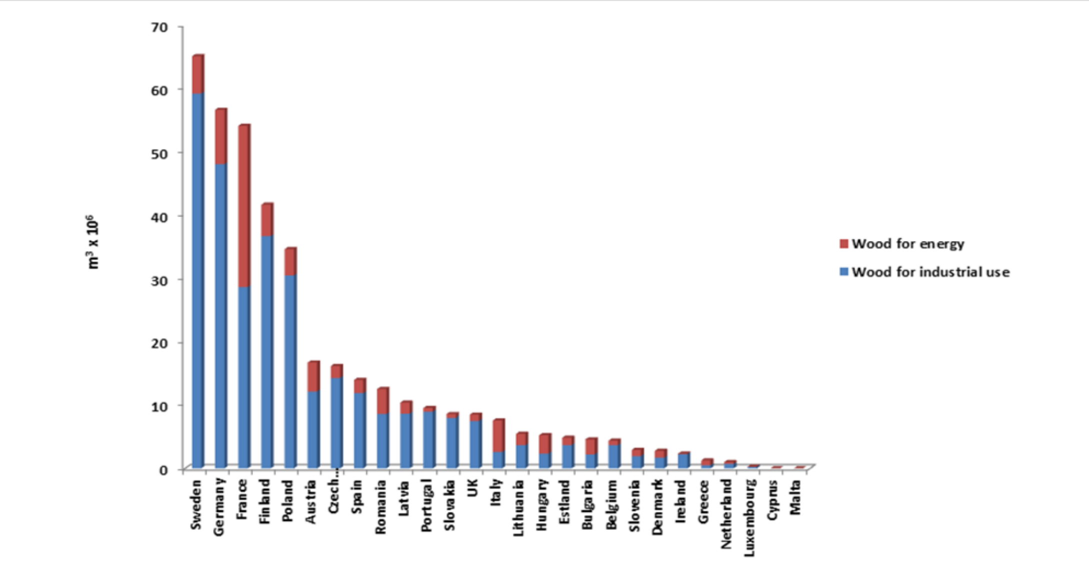


Figure 9: Roundwood for industrial and energy use. [53] (SAHYOG database)

Besides the production of the roundwood and fuelwood, also side products are generated that have additional applications. This concerns the bark, estimated at 51.1 Mm^3, forest residues and other woody biomass, estimated at 72.6 Mm^3.[51] In addition, several side products are generated in the processing of industrial round wood, such as dust, chips, shavings, black liquor…. It is estimated that 103.7 Mm^3 industrial by-products, including black liquor, are used for bioenergy generation. Additionally, 103.7 Mm^3 industrial by-products, 20.6 Mm^3 post-consumer wood, and 32.1 Mm^3 pellets are used for the production of bioenergy. The NREAPs give that in EU-27, roughly 29.9 MTOE bioenergy is generated from direct forestry resources and 31.7 MTOE from indirect forestry resources (2006).[j]

For *India*, the total growing stock is estimated at 6047.15 Mm^3, which comprises 4498.71 Mm^3 from forests and 1548.42 Mm^3 from outside the forests. Several estimates are available for the production of industrial roundwood and fuelwood. To make a comparison with the EU-

[j] Excluding EE and IT.

situation, the FAO data have been taken as a base, indicating a production of 23 Mm^3 ub of industrial roundwood, and 309 Mm^3 ub of wood fuel. According to the Indian state of forest report, only 27% of the fuel wood comes from forests, the majority from trees outside the forests.

It was apparent from survey of the sources mentioned in SAHYOG inventory, as all as discussion with various stakeholders, that in India forest and forest products are very difficult to be considered as a resource for any biomass conversion applications. Until recently a systematic large-scale exploitation of woody biomass from forestry could not be considered as a resource for the bio-economy. However recent concerns about increase in forest cover and forest management also linked to economics bring the forestry and its related industries to the discussion area. The combination of forest management and afforestation can go hand in hand to increase wood biomass production in India. A large potential is seen in bamboo exploitation.

3.2.5 Current status of waste

The *EU* waste management policies aim to reduce the environmental and health impacts of waste and to improve the EU's resource efficiency. The aim is to reduce the amount of waste generated and when waste generation is unavoidable to promote is as a resource and achieve higher levels of recycling and safe disposal of waste. Also in *India* the key priorities are waste avoidance and minimization, recycling, safe disposal, integrated waste management facilities and the use of cement kilns for hazardous waste incineration.

In *Europe*, biodegradable waste" is defined in the Landfill Directive (1999/31/EC) as "any waste that is capable of undergoing anaerobic or decomposition, such as food and green waste, and paper and paperboard". The term "bio-waste" is more narrow and is defined in the Waste Framework Directive as "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants". Bio-waste does not include forestry or agricultural residues, or other biodegradable wastes such as natural textiles, paper or processed wood. The waste also excludes manure that is reused as fertilizer in agriculture, agricultural non-hazardous residues that remain at the site of generation as part of the biological cycles, as well as by-products of food production that never become waste and are for instance used for feed. (Europe in figures, Eurostat yearbook, 2012). Since the regulation of waste statistics is implemented (EC 2150/2002) EU members are obliged to report data on waste amounts to Eurostat. These includes 48 categories of waste, and a distinction is made between hazardous and non-hazardous. As indicated in some studies, doubt exist about the consistency of the data reported by the different MS, since the amount of waste is not always reflected by the number of inhabitants. Further improvements on the harmonization, and the waste collection system enabling registration would be needed.

(1) **Municipal waste**, i.e. waste collected by the municipalities and consisting of household waste and similar waste from offices and small businesses, accounts for 251.6 kton or 500 kg /capita per year (Eurostat, 2011), and represents more or less half of the biodegradable wastes. D. Hogg et all. showed that the composition of municipal waste is country dependent, and calculated an European average of 34% for the

biodegradable fraction (for EU21, excl. Czech republic). [54] This corresponds well with the value of 38% calculated by ETC/SCP for EU28 for the period 2008-2010.[55] Therefore, it can be estimated that 85 to 95 kton of municipal waste is biodegradable.

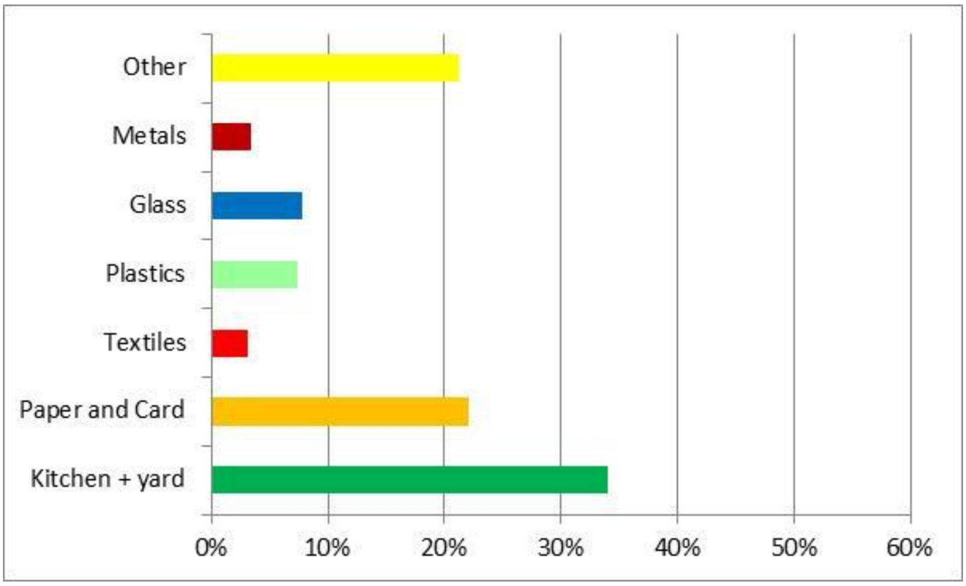


Figure 10: Estimated average composition of municipal waste.[54]

The EU Waste Framework Directive and landfill directive set binding targets for recycling municipal solid waste and diverting biodegradable municipal waste from landfill. Nevertheless, large differences are seen in the municipal waste management system between countries (see Figure 11).

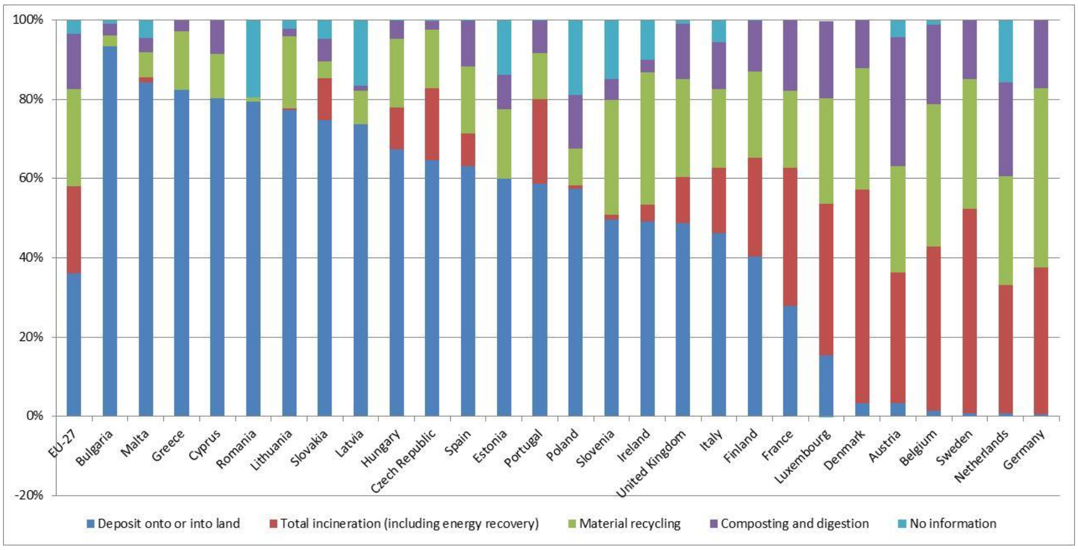


Figure 11: Treating process used for municipal waste in the different EU-27 countries (Eurostat, 2010).

(2) Waste from economical activities and households: In 2010, the total generation of waste from the different economic activities and households amounted to 2.5 Mton or 5.0 ton/capita in the EU-27.[56] This includes 0.1 Mton or 0.2 Ton/capita classified as hazardous waste. The distribution over the main categories is given in Figure 12.

Almost 70% of the waste is composed of mineral and solidified wastes. The category recyclable wastes includes paper and cardboard and wood, amongst others.

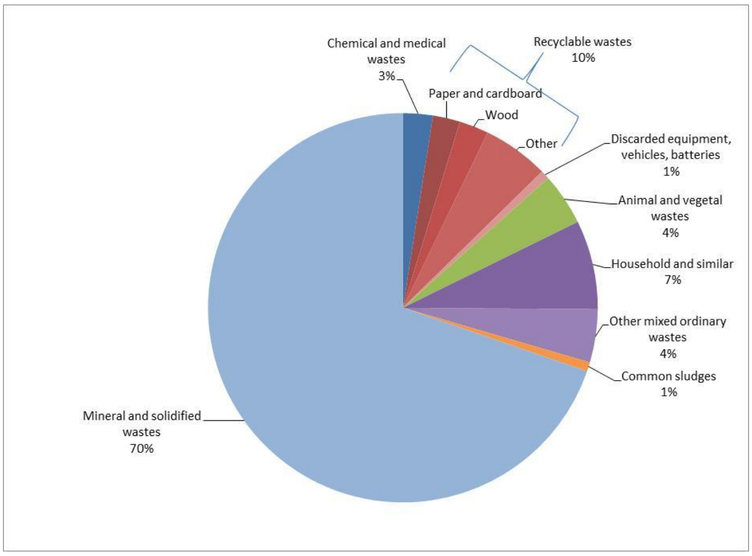


Figure 12: Distribution of the different waste categories in EU-27 (Eurostat, 2010).

Roughly 17%, or 423.7 kton, of this waste is biodegradable. It is composed of 56.6 kton paper and cardboard (2.2%), 60.8 kton wood waste (2.4%), 108.5 kton animal and vegetable waste (4.3%), 184.9 kton of household and similar waste (7.4%)[k], and 19 kton of common sludges (dry, 0.8%).

The current treatment of the different biodegradable fractions is shown below. It shows a high recycling/recovery rate for paper and cardboards (94%), animal and vegetable wastes (87%), common sludges (67%) as well as wood wastes (45%). Landfilling, on the other hand, is the most predominantly treatment for household waste.

k. Total household waste, not all is biodegradable.

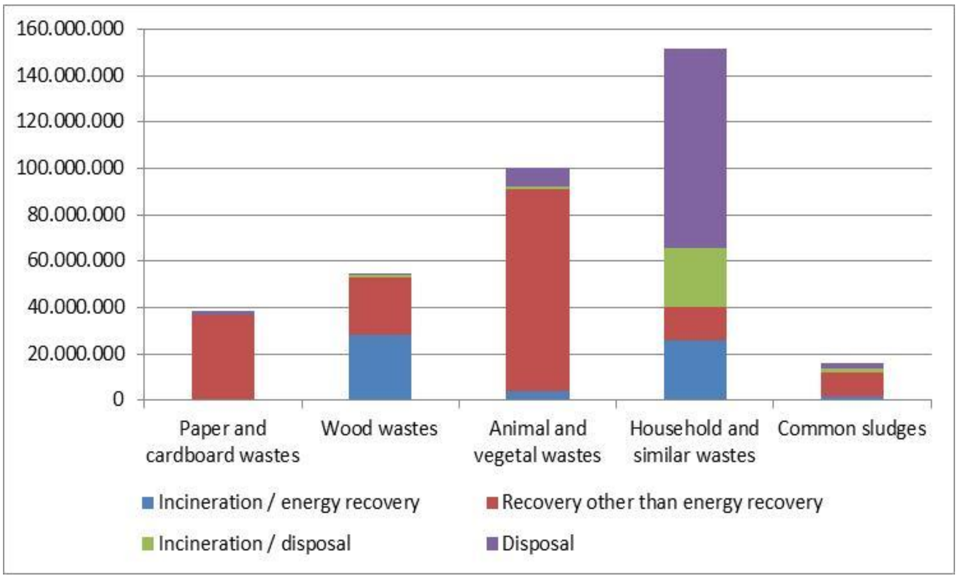


Figure 13: Amount of the different biodegradable wastes (in Tons) according to their treating methodology in the EU-27 (Eurostat, 2010).

(3) **Sewage sludge:** the total quantities of sludge in the EU27 were currently estimated at 10.1 Mtons (dry, 2006-2007). Of this, nearly 40% was estimated to be spread on the land for agricultural use. The recycling of sludge in agriculture varied greatly among MS, some countries like France, UK, Spain, Ireland, Slovakia recycling more than 60%, others like Greece, Netherlands, Belgium, Slovenia and Romania less than 10%. Sludge contributed less than 5% of the total amount of organic manure used on land, and sludge was applied to less than 5% of agricultural land in the EU. Other utilization routes were reported: incineration (19%), landfill (17%), compost (12%) and other uses (12%).[57,58]

NREAP (2006) indicates that in total 10.8 MTOE[l] bioenergy is generated from waste, including is 2.4 MTOE from industrial waste, 7.4 MTOE from municipal waste and 1.0 MTOE from sewage sludge. The estimated energetic potential of the biodegradable waste in EU-27 amounts 30.8 Mtoe and is given on the basis of data collected from existing databases and reported in SAHYOG biomass inventory (Figure 10).

l Based on the available member states, excluding EE,HU,IE,IT and LV.

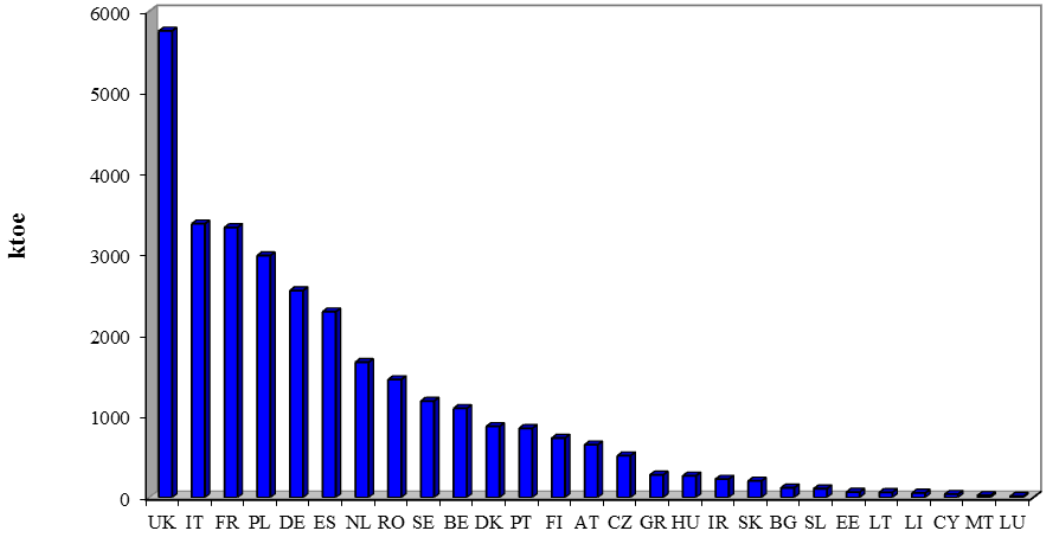


Figure 14: Energetic potential of the biodegradable waste in EU-27; SAHYOG database[53]

In *India*, economic development and population growth has led to rapid industrialization and urbanization, which has, in turn, led to increase in the consumption of large amounts and varied types of goods and production of a wide range of waste materials. This is the main reason for a significant increase in quantity and variety of waste generation in urban areas. Even rural areas have not been an exception to this phenomenon. Figure 15 shows the solid waste generation in top 10 urban cities in India, where the maximum waste generation is shown in the capital city, New Delhi.

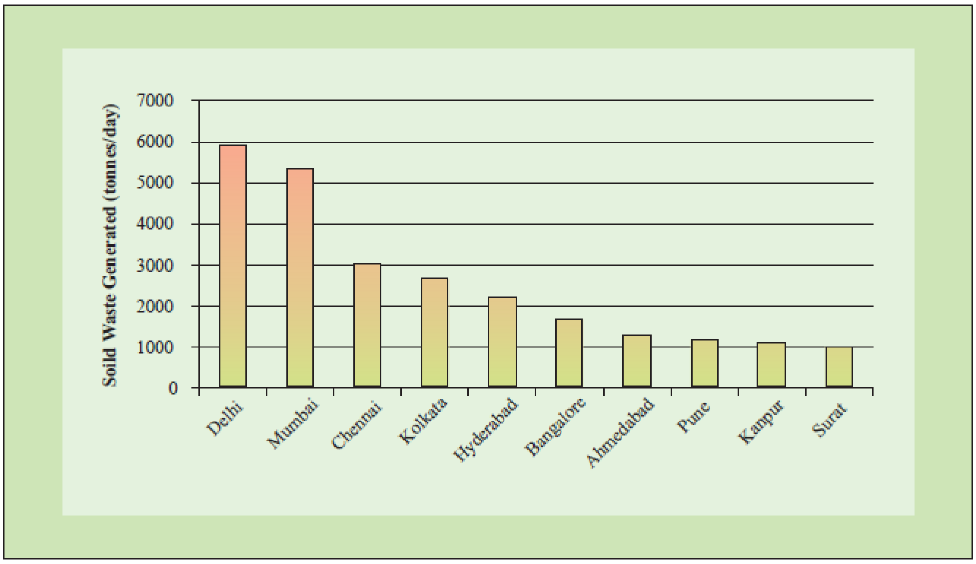


Figure 15: Solid waste generation in the top ten cities of India (2006-2007).[59]

The overall effect resulted in abundant waste generation which can be utilized as an alternative source of bio-energy/fuel. In India, the main sources of biowaste are:

(1) Municipal Solid Waste (MSW): based on an analysis of 366 cities, the MSW of India was estimated to be 67.6 Mton/y or 180 kg per capita per year (2011). The biodegradable fraction of MSW was found to be on average 51%, corresponding to a calculated total of 34.5 MTon per year.[60] Since the amount of MSW generated is not available, extrapolations were done on population basis, in order to calculate the actual amount of waste generated and the power generation potential that can be derived from it. Although the amount of MSW generated in India is very high, unlike other western countries, it differs greatly with regard to the composition and hazardous nature. [61,62,63] Many categories of MSW are found such as: food waste, rubbish, commercial waste, institutional waste, street sweeping waste, construction and demolition waste and sanitation waste. MSW contains compostable organic matter (fruit and vegetable peels, food waste), recyclable (paper, plastic, glass, metals etc.), toxic substances (paints, pesticides, used batteries, medicines) and soiled waste, blood stained cotton, sanitary napkins, disposable syringes.[64,65] Figure 16 illustrates the composition of waste generated in a typical Indian city.

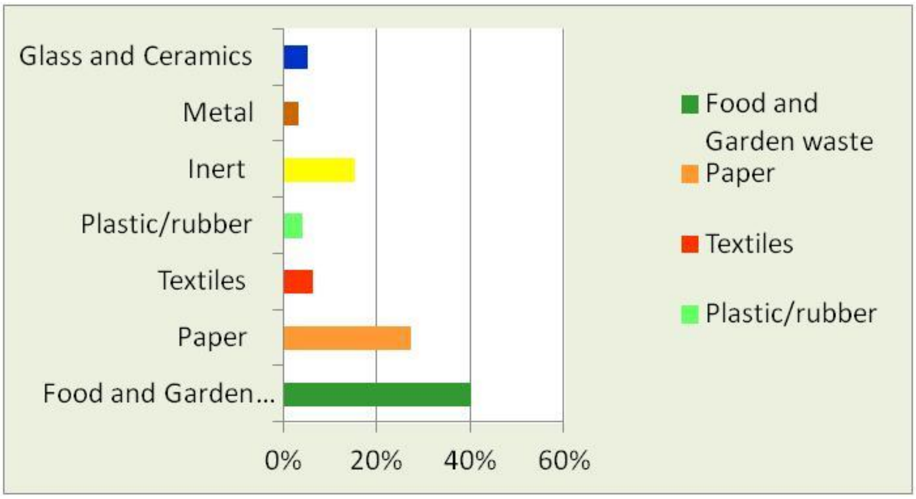


Figure 16: Composition of Solid Waste in a typical Indian city (2005).[66]

(2) Sewage Sludge: Sewage is the untreated municipal liquid waste. It contains about 99.9% of water, while remaining content may be organic or inorganic. In urban cities in India around 38 billion liters of total sewage is generated out of which only 12 billion litres is treated due to lack of Sewage Treatment Plants. 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 caloric value of sewage sludge depends exclusively on its organic matter content and ranges between 10 and 20 MJ/kg dry matter.

(3) Industrial Waste: In *India* ~4.5 MT of hazardous waste is generated annually during different industrial processes like, electroplating, various metal extraction processes, galvanizing, refineries petrochemical industries, pharmaceuticals and pesticide industries. Out of these ~1.7 MT of waste are recyclable; 1.89 MT is incinerated and ~2.5 MT is disposed in secured landfills.[67,68] Industrial waste includes garbage, refuse, other discarded or salvageable materials including solid, liquid and semi-solid materials, resulting from industrial, agro-industrial, commercial and mining activities. The industrial waste is divided into the following two categories on the basis of its chemical nature:

a. ***Hazardous waste:*** The World Health Organization, United Nations Environment Programme, and the world bank has defined hazardous waste as "any waste excluding domestic and radioactive waste, which, because of its quantity and physical, chemical and infectious characteristics can cause a significant hazard to the human health and/or the environment when improperly treated, stored, transported or disposed. The major potential hazardous waste is generated from the industrial sectors such as, pesticides, drugs and pharmaceuticals, petroleum refineries, textiles, dyes, fertilizers, tanneries, paint and chlor-alkali. Hazardous waste from these sectors contains heavy metals, cyanides, pesticides, complex aromatic compounds and other chemicals that are toxic to humans, plants or animals and are flammable, corrosive or explosive, or have a high chemical activity. According to the estimates of Ministry of Environment and Forest (2008) about 6.23 MT of hazardous waste is generated in India from 36165 hazardous waste producing units.[69]
b. ***Non hazardous waste:*** In India, the major generators of non-hazardous industrial solid waste are thermal power stations producing coal ash, mineral exploration activities producing mine tailings, steel mills producing blast furnace slag and steel melting slag, non-ferrous industries such as aluminium, zinc and copper producing red mud and tailings, sugar industries generating pressmud, paper and pulp industries producing lime sludge, and fertilizers and allied industries producing gypsum. The major non-hazardous industrial waste generated in India is estimated to be ~290 MT per year. [70,71] Non-hazardous or ordinary industrial waste is generated by industrial or commercial activities, but is similar to household waste by its nature and composition. It is non-toxic, presents no hazard and thus requires no special treatment. In particular, it includes ordinary waste produced by companies, shopkeepers and trades (paper, cardboard, wood, textiles, packaging, etc.). Due to its non-hazardous nature, this waste is often sorted and treated in the same facilities as household waste. Major industries showing the waste and the process applied for its conversion are tabulated below.

Table 8: Some of the major organic waste producing industries, their prominent wastes and the method for waste conversion.

Industries	Prominent Wastes Generated	Treatment Option	Application
Sugar Mills	Sugar bagasses Pressmud Sugar molasses Fermentative Yeast biomass	Combustion Gasification Composting Fermentation Biomethanation	Heat and Power Fertilizer Ethanol synthesis Biogas/digestate production
Slaughter houses	Organs, Tissues, Blood, Hides, Animal excreta and Carcass	Biomethanation	Biogas/digestate production
Paper mills	Pulp Paper shavings Wood wastes and Paper boards	Biomethanation Combustion Combustion Gasification	Biogas/digestate production Heat and power Heat and power Biogas/digestate production
Dairy Plants	Whey and Milk cream	Biomethanation	Biogas/digestate production
Sago factories	Starch materials & peels	Biomethanation	Biogas/digestate production
Tanneries	Hides and skins	Acid treatments and biomethanation	Biogas/digestate production
Animal Husbandries	Animal excreta and body fluids	Biomethanation	Biogas/digestate production
Fruits & vegetable processing units	Pulp wastes	Biomethanation	Biogas/digestate production

3.2.6 Potential of current biomass production for bioenergy/chemicals

In the EU-project Biomass Futures a detailed analysis was made of the *EU-27* biomass potentials for bioenergetics purposes. The study indicated a total potential of 314 MTOE (2004), composed of the 42 MTOE for waste, 107 MTOE for agricultural biomass, and 164 Mton for forestry based biomass. More recent data (reference years 2008-2012) based on SAHYOG biomass inventory[53] confirm that forestry and agriculture are the major sources of biomass for bioenergetics purposes as indicated in Figure 17.

The detailed breakdown is given in Figure 17. Since forest and forestry products are considered to be a difficult resource for India, also for Europe the discussion will be limited to waste and agricultural residues and landscape care wood.

Figure 17: Biomass potential of the three main categories (waste, agriculture and forestry) in MTOE as estimated in Biomass Futures (2004).[72]

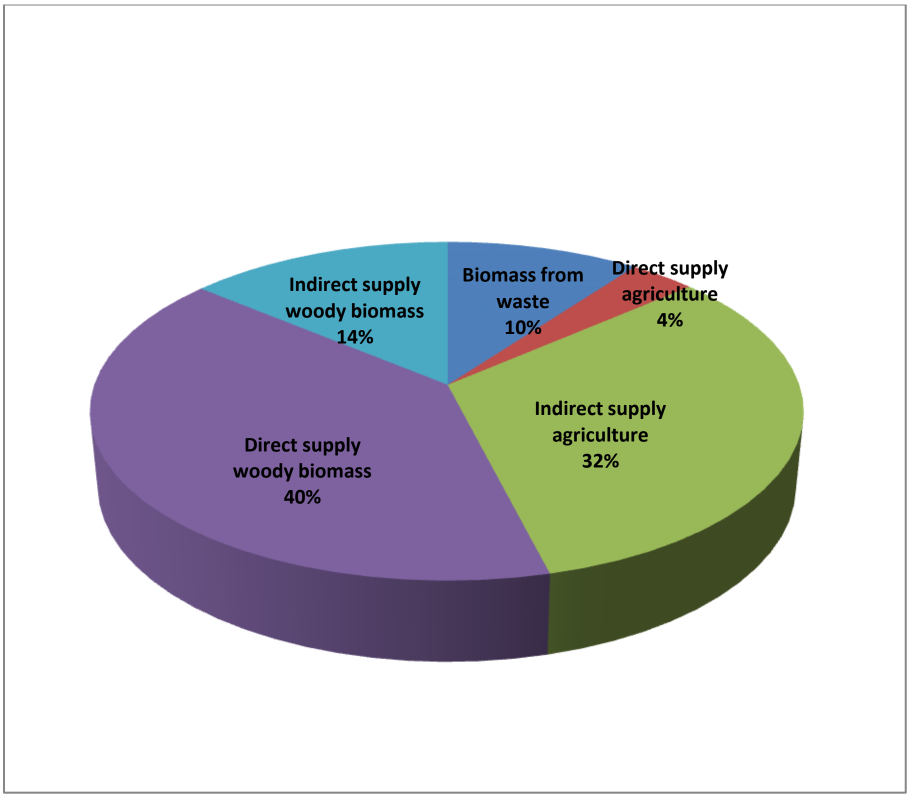


Figure 17: Biomass share of different sources (MTOE) in EU-27 (2008-2012).[53]

Data on the agricultural residues are very scarce since current statistics on agricultural productivity chiefly focus on product yields. Calculations have been done to estimate the availability of crop residues in EU-27 MS on the basis of EUROSTAT data referring to the year 2011 following the procedure described by Scarlat et al.[73] Agricultural residues comprise mainly straw, leaves and stalks from the following crops: wheat, barley, oats, rye, maize, sunflower, rapeseed and rice. The total amount of crop residues available in EU-27 in the year 2011 is estimated at 109 M dry tons. Most of the crop residues are available in the countries with a large agricultural sector and high agricultural production: France, Germany, Romania, Spain, Italy, Hungary and Poland and United Kingdom. The contribution of wheat (40%) is the highest followed by maize (22%) and barley (20%), rapeseed (7%) and sunflower (5%), as shown in Figure 18. Biomass Futures estimates a biomass potential of 22.9 MTOE (2004).

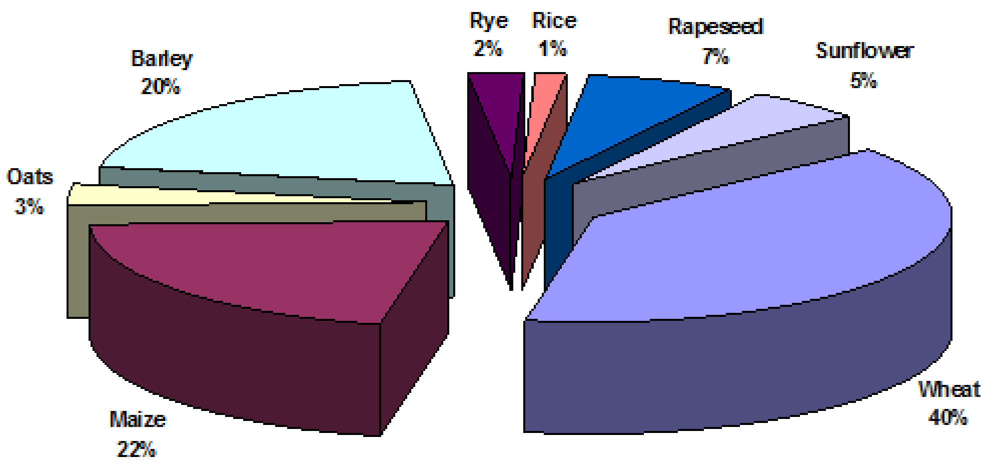


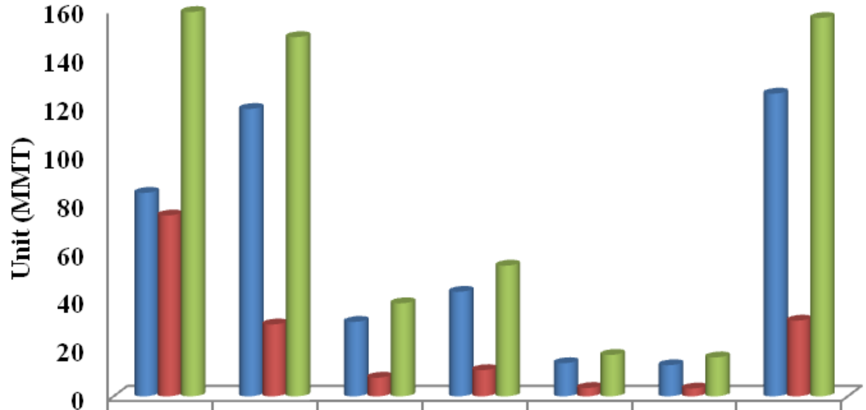
Figure 18: Share of crop residues produced in EU-27 in 2011; (SAHYOG database)[533]

Also in horticulture pruning and cuttings of orchards, vineyards and olive trees produce a woody biomass that could be used as second generation resource for the bio-economy. The amount of pruning and cuttings was calculated in EUwood, as 75% harvest of the annual increment, and estimated to be in total 15.9 Mm^3, mostly produced in Italy, Spain and Greece.[74] Biomass futures estimates a bioenergy potential of 9.4 MTOE (2004).

In livestock production, manure forms a source that is suitable for anaerobic digestion. It is estimated that in EU-27 in total 1 400 Mton of fresh manure is produced in the EU-27, which France, Germany, the UK and Spain accounting for half of the total production. Biomass futures estimates a bioenergy potential of 56.8 KTOE (2004).

The potential of bio-wastes from food industry, which include olive pomaces, pulps, molasses, waste from fruit and vegetables are difficult to quantify due to the lack of regional data and their distribution. Furthermore, some of these products, find application in animal feed for which no statistics exists. In BioBoost, an assessment was made from the potential of the residuals and wastes from the olive and grape processing industry which can be used for energy purposes. It was estimated to be 14.3 Mton or 1.2 MTOE (2013).[75]

For *India*, 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 (159 Mton), wheat (149 Mton) and several cash crops (156 Mton) apart from other sources like maize, pulses, bajra and jowar which also contributes significantly (see Figure 19).



	Rice	Wheat	Maize	Pulses	Bajra	Jowar	Cash Crops
Net	84.118	118.816	30.765	43.216	13.693	12.862	125.154
Used	74.772	29.704	7.691	10.804	3.423	3.216	31.288
Gross	158.89	148.52	38.456	54.02	17.116	16.078	156.442

Figure 19: Biomass supply from by-products of agricultural crops in India in Mton [53]

Thus, apart from the used biomass for several household purposes, the total biomass potential of agricultural by-products in India is 429 Mton (Figure 20). This biomass potential of agricultural by-products in India consists of straw, husk, stalk and stover of rice, wheat, maize, bajra, ragi, pulses and grams. Moreover, an increasing trend has been observed of burning the crop residue (husk and straw) by the farmers in some states like Haryana and Punjab (leading to huge air pollution). 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 losses in cereals (paddy, wheat, maize, bajra and sorghum) during harvesting threshing, collection, cleaning, drying, packaging and transport amounted to 2.8-4.7%, while the losses in case of pulses and oilseeds were observed to be in the range of 4.6.1% and 2.8-10.1%, respectively. The farm operation losses in cereals, pulses and oilseeds constituted about two-thirds of the total losses. Postharvest losses in the horticultural crops are the highest (6-18%) among all other crops. Thus, reduction of postharvest losses and processing of marketable surplus into value added products appears to be most important goal for sustainable development. Thus, improving harvesting efficiency, production of high value-low volume compounds, development of fuel management and conversion technologies for agricultural residues would have to be the focus for development of future policy and regulatory framework.

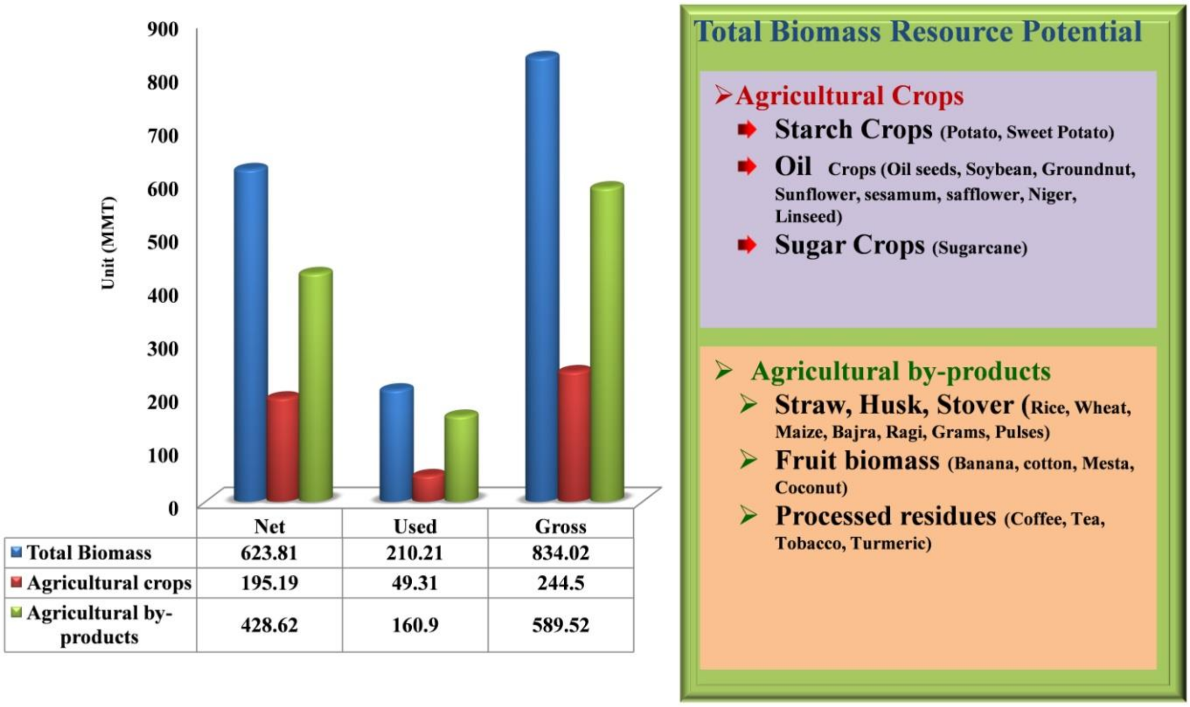


Figure 20: Available Biomass Resource Potential in India (in Mton).[53]

3.2.7 Biomass potential for bioenergy/biochemical production from non-food plants

Plant species under arable cropping.

Biomass production for non-food purposes with arable crops in *Europe's* temperate climate is currently dominated by maize, wheat and rape. Triticale, being more drought resistant than wheat, as yet holds a relatively small share. Particularly maize and rape have strong negative impact on the environment including soil properties; thus an increasing number of new crops is studied to prepare a shift to sustainable arable cropping for non-food biomass production. Sweet sorghum (*Sorghum bicolor*) is an arable C4 plant with a short growth cycle facilitating double cropping, high water, nutrient and light use efficiency, broad agro-ecological adaptation potential and rich genetic diversity. It produces sugar in the stalk and starch in the grain, providing the potential to produce fuel feedstock, food and feed in various combinations. Its characteristics are shown in Table 9. Sugar cane is also considered to be a sustainable biomass crop for its high energy balance and high GHG reduction potential. *Camelina sativa* is an oil plant that grows well on marginal land, is cold-tolerant and has an oil yield of 35-38%. *Brassica carianata* (Ethiopian mustard) oilseed has been developed as a biofuel feedstock (Resonance™) by Agrisoma Biosciences (Canada). It is suited to semi-arid areas and produces seed with 44% oil content.

In *India*, the major biomass sources from arable crops which come direct from agricultural land consist of sugar crops followed by oil crops and starch crops. The by-products obtained from agriculture were considered as the major source of the biomass in India. The energy crop sweet sorghum (*Sorghum bicolor*) is raising considerable interest for the simultaneous production of food and bioenergy. However, the underused and unutilized crop products should be included in the bio-economy chain. Furthermore, the produce of marginal farmers should also be taken in to consideration at regular basis. Therefore, future strategies of India will be securing adequate food supply and to make maximum utilization of agricultural produce in the form of food, feed and fuel.

Perennial species

Cultivation of biomass grasses or other perennial biomass crops, short rotation forestry and short rotation coppice imply lower environmental pressure compared to traditional energy crops.

In *EU27*, grassland is e.g. seen as a net carbon sink in most European countries, having overall mean of 74±10 g/m^2 (expressed as C)annually[76], it shows high biomass productivity and a positive impact on biodiversity. Perennial biomass crops grown as buffer strips, shelterbelts or windbreaks can additionally provide valuable ecosystem services, reducing erosion and the risk of landslides as well as diffuse pollution of soil and water resources and preserving or enriching farmland biodiversity. Land use changes towards perennial cropping for non-food use, as currently occasionally done, can be very useful if applied to marginal land, to increase soil fertility by efficient carbon sequestration. Mixtures are considered superior to monocultures because of greater ecosystem services. The use of legumes in such mixtures additionally reduces the need for fertilizers and protects the environment against the risk of over-fertilization with consequences such as unnecessary N_2O emissions and eutrophication of water resources.

In EU, several perenials have been the subject of research as an alternative high yielding bioenergy crop. The most common ones are summarized in Table 9.

Table 9: overview of the most common species considered as bioenergy crop in EU.[77-83]

Species	Yield (ton DM /ha/yr)	Energy[79] (GJ/ha)	Conditions	Extra
Arable crop				
Sweet sorghum *Sorghum bicolor L.Moench*	5-30	250-422	Mediterranean Water:300-700mm/y Sensitive to low T	Fermentable carbohydrates in stem
Perenial crop				
Giant Miscanthus (C4) *Miscanthus x giganteus*	10-30 5-15 (DK) 4-30 (DE) 10-15 (UK) 30-32 (IT)	170-528	Temperate climate central and S EU Sensitive to frost Water:700-800mm/y Soil similar maize	>30 y research Yield after 3y, Harvestable:15-20y Area: 0.018 Mha[m] (UK, IE, FR, DE)
Giant reed (C3) *Arundo donax*	15-25 (GR,ES,IT)	245-570	Mediterranean Sufficient water	Feedstock M&G ethanol cellulosic plant in Crescentino (IT). Major energy crop US
Switchgrass (C4) *Panicum virgatum*	10-25 19 (FR)	174-435	Temperate climate central and S EU Sensitive to frost Water:450-750mm/y	Major energycrop in US. Low lignin strains Area: 0.050 Mha[m] (RO)
Tall wheatgrass (C3) *Elymus elongatus* *Elytrigia elongate* *ssp. Ponticus*	5-12		Temperate climate central and S EU Semi-arid Water>300mm/y	Harvestable: 30 years
Reed canary (C3) *Phalaris arundinacea*	6-12 5-12 (FI) 6-12 (UK)	100-130	Cool climate + wetlands	Investigated as raw material for paper pulp and biofuel Area: 0.019 Mha[m] (FI)
Silphium perfoliatum (C3)	18-28		Temperate climate	Yield after 2y (DE) Only research trials

[m] Data are for 2011

				No herbicides and good Protection for soil erosion
SRF				
Eucalyptus	10-26	1000	S EU Water:870-1085 mm/y	Cultivated in S Europe for paper pulp production
SRC				
Poplar	7-28	173-259	Cool and temperate climate NW, central & S EU Water:1000mm/y	Area: 0.016 Mha[m] (IT; DE, DK)
Willow	10-30	187-280	Cool climate Water>350mm/y Not frost sensitive	Area: 0.020 Mha (SE, PL,DK,DE)

Several other perennial species are currently considered to be also suitable for high yielding biomass production under unfavourable environmental conditions.[85,86] Cardoon (*Cynara cardunculus*) is a perennial C3 herb native to the Mediterranean region thus well adapted to high temperatures and low precipitation. In conditions of average rainfall (> 450 mm/yr) yields are about 14 ton/ha of dry matter per year, of which nearly 8-10% are oil achenes. Also CAM plants such as agaves and cacti are of particular interest with regard to biomass production in arid regions since they can survive for many months without water and use applied water more than 10 times more efficiently than e.g. maize, Sorghum, Miscanthus and Switchgrass. Agave leaves are low in lignin (3-15% by dry weight) and high in cellulose (up to 68%) and accumulate soluble nonstructural carbohydrates. *Sida hermaphrodita*, a soft woody crop allowing for 15-20-year plantations, grows well under many site conditions including temporary drought and frost, and comparatively well in poor sandy soils. It is currently being cultivated in marginal lands in Poland. *Sida* biomass shows low moisture content (11-20%) directly on the field, allowing for easy baling. The species would meet sustainability criteria of next-generation biofuels and take advantage of existing agricultural infrastructure. Castor bean is being developed as a potential industrial-scale biofuel feedstock. It is a tropical non-edible, high oil-yielding crop (40-50% seed oil content) with high tolerance for growth under harsh environmental conditions, such as low rainfall and heat. Its close relative, *Jatropha curcas*, is another tropical perennial species of interest that grows well on marginal land and under drought conditions and has seeds with high oil content (~40%). New strains with 75% oleic acid content, compared to the typical 45% percent, as well as methods to remove toxic compounds have recently been developed. Being a wild species, little is known about best cultivation practices and breeding potentials, but intensive research, including efforts of Neste Oil Finland and Galp Energia Portugal, is being carried out on various aspects concerning its use for biofuel production. A salt marsh halophyte native to the west coast of the USA and Mexico, *Salicornia bigelovii* (dwarf saltwort / dwarf glasswort), is of interest as specialist feedstock growing in desert environments yielding seed oil contents of 30%. It can be irrigated with seawater and is being grown extensively across the globe, including India.

Short rotation plantations in the EU-27 per definition refer to fallow or set-aside agricultural land. They can be divided in two different specialized forestry systems: Short rotation forestry

(SRF) and short rotation coppice (SRC). Both of them consist of high-yielding varieties, densely planted on the yield, regenerating from stools and tolerating several rotations, but differ in the period of rotation (SRF: 8-20 years – SRC: 2-4 years). The native species traditionally used as SRF in central Europe and Scandinavian countries have been among others: poplar, alder, ash, aspen and birch. The latter two are relatively tolerant to drought. In Spain and Portugal, Eucalyptus (see Table 9) has been widely used in the paper industry. However, a shift to alternative high-yielding woody species is necessary in the light of the many disadvantages of Eucalyptus regarding soil and water impacts. A novel SRF crop developed in the Mediterranean with high potential for the biomass sector is Siberian elm (*Ulmus pumila*). It is already successfully being used as feedstock in several areas above 300 mm of annual rainfall. Some reports from Spain and Italy trials, in very poor soils have shown that Siberian elm can grow with low inputs, producing as high as 12 oven dried tonnes per year. Genetic differences, however, play a major role, calling for some development and breeding. With regards to SRC, willow and poplar are the most common species planted in Europe, with plantation lifetimes of more than 20 years (see Table 9). For both species a broad variety of cultivars exist (e.g. 7 poplar varieties and 6 willow varieties recommended for cultivation in Germany). Willow is mainly produced in Sweden, Finland, Denmark, the Netherlands, UK and Ireland. In warmer climates, such as the Mediterranean area, poplar and robinia are grown. Short rotation plantations can provide good soil protection and may have positive function on farmland biodiversity. Consequently, given SRC´s high yields and relatively low environmental pressures, they can play an important role in future lignocellulosic biomass demand.

Short rotation plantations have a high potential for the production of biomass in *India*. The plantations includes *Leucaena*, *Acacia* and *Eucalyptus* on arid land.[87] Eucalyptus plantations also have a high potential for the production of biomass from Indian saline and sodic soils.[88]The biomass potential of *Melia azedarach*, *Pongamia pinnata*, *Alstonia scholaris*, *Populus deltoides* and *Ailanthus excelsa* were reported to maximize in short rotation effluent irrigation system in Palwal (70 km from Delhi).[89] The non-food energy crops (e.g. *Jatropha curcas*, *Pongamia pinnata*, *Azadirachta indica*) are other perennial species to be considered for the biomass production. Moreover, Coconut (mostly growing in coastal plains of India), is a tall stately palm and its leaves and husk is a potential biomass source. Pine (growing mainly in Himalayan region), is also produces fine leaves.

Aquatic biomass

Europe: Algae are seen as a promising source for sustainable biomass production. They *do* not compete for food crop resources as they can be cultivated on land area not suitable for agriculture or forestry such as sealed or contaminated industrial fallows, and they are adaptable to diverse environments. Out of the 40000-60000 known algae species currently only 1% are actually commercially utilized. In 2009 the global use of algal biomass was 9 Mt, valued at 3.5 billion EUR. Microalgae can be cultivated on non-arable land at very high production efficiency per area land: Compared to maize (15-20 ton dry matter per hectare and year), forest trees (4-7 t/ha/yr) and short rotation coppice (6-20 ton/ha/yr), open-pond cultivated microalgae can yield 40-60 ton/ha/yr. Furthermore microalgae can use CO_2 from industrial and power plants. A recent German study [Skarka, KIT] suggested a total potential of 45 Mton in the EU-27 for sites with biomass costs less than 2,000 US$/t on a dry matter basis, with most of the potential found in the southern part of Europe, particularly on the

Iberian Peninsula. Microalgae cultivation, however, needs research towards suitable solutions to reduce cost for production and processing. Also research is needed to demonstrate the full bio-refinery whereby all constituents of the algae are valorized.

Also in *India*, algae have recently received tremendous attention as biomass source for the production of renewable energy. Some of the main characteristics which set algae apart from other biomass sources are that algae can have a high biomass yield per unit of light and area, a high oil or starch content, do not require agricultural land, fresh water is not essential and nutrients can be supplied by wastewater and CO_2 by combustion gas. Thus, various government and private agencies are backed by big investors in India for algal fuels.

Table 10: Indian contribution towards algal bio-fuels research (Biotechnology and Biological Sciences Research Council 2011)

S.N.	**Institute**	**Research Group**	**Research Area/ reference**
1.	Central Salt and Marine Chemicals Research Institute, Bhavnagar	R. Mahesh	Cultivation of *Gracilaria*, *Gelidium*, *Kappaphycus* etc., Ethanol
2.	University of Madras	R. Rengasamy	Development of germplasm of *Botryococcus braunii* and bio-deisel production. Biogas production from seaweed. Outdoor cultivation of *Sargassum*
3.	International Center for Genetic Engineering & Biotechnology, New Delhi	Shams Yazdani and Shashi Kumar	Genetic modification and enhancement of growth rate of marine and fresh water green algae (*Chlamydomonas* and *Chlorella* sp) and cyanobacteria, Biofuel production
4.	Central Food Technological Research Institute, Maysore	G.A. Ravishankar	Isolation and characterization of hydrocarbon producing micro alga *Botryococcus braunii*
5.	Bio-energy Division, Defense Research Laboratory, Tezpur	Simrat Kaur *et al*	Algal diversity as a renewable feedstock for biodiesel
6.	Vivekananda Institute of Algal technology, Chennai	Sivasubramanian	Mass cultivation of fresh water micro algae. Developing algae based technology to treat industrial effluents and wastewater (Phycoremediation). Biogas, bio-ethanol and biodiesel production

Some research groups are also working on the biomass production potential of waste water alga Chlorella vulgaris [90] *and utilization of industrial effluent for cultivation of Spirulina.* [91] *Microalgae are the fast-growing plants that can be grown in any waste land with yield 15–300 times more than the terrestrial bioenergy crops. There are many microalgal species like Chlorella, Spirulina, and Dunaliella grown in different parts of India commercially for bio-fuel production.*

3.2.8 Potential of biodiversity for new biomass production

Biodiversity of plant material for agricultural and forestry biomass production

For a bio-economy, which aims to make use of the full range of natural and renewable biological resources, agricultural biodiversity largely determines the exploitation potential.

The *EU-27* comprises a large richness of plant species and varieties used for biomass production. However, the genetic diversity currently exploited represents only a small portion of what is generally available. As an example, Germany counts as many as 440 native medicinal plant species of which only 75 are being cultivated. 24 of these species currently account for 92% of the total production of medicinal plants in Germany. Europe's genetic resources, including seedbank resources, as well as plant breeding represent important pillars to address the challenge faced by the bio-economy sectors and to adapt to climate change. In addition, new approaches for quantitative determination of plant performance (i.e.: phenotyping), and modeling, have been developed in the EU-27 for more efficient evaluation and prediction of plant production potentials in different production systems. This also applies e.g. to so-called working trees in agroforestry systems, such as fast-growing fertilizer trees for land regeneration and soil health, fruit trees, fodder trees, timber and fuelwood trees or medicinal trees, which are currently systematically being investigated to estimate the minimum productivity under most unfavorable conditions. Breeding for biotic and abiotic stresses e.g. may boost stabilized yields, but also the sustainability of natural resources by reducing environmental footprints (e.g. less irrigation, PPPs and fertilisers). In addition to quantity, also quality of the biomass can be modified and adjusted to the specific requests of bio-economy sectors by the development of new varieties. This may include breeding of new plants to produce specific pharmaceuticals or their precursors. Domestication of new crops and algae by the help of breeding additionally provides opportunities for development of alternative sources of plant biomass.

India can be conveniently divided into ten major regions, based on the geography, climate and pattern of vegetation seen. Each of these regions contains a variety of ecosystems such as forests, grasslands, lakes, rivers, wetlands, mountains and hills, which have specific plant species. According to a MoEF Report (1999), the country is estimated to have over 49,219 plant species representing 12.5% of the total world diversity. A large number of crops in different crop groups namely cereals (rice, little millet), grain legumes and oilseeds (black gram, green gram, horse gram, moth bean, pigeon pea, sarson), vegetables (cucumber, eggplant, greater yam, ivy gourd, leafy mustard, pointed gourd, ridge gourd, round gourd, snake gourd, taro and yam), fruits (bael, banana, citrus, jackfruit, jamun, karonda, khirni, mango, phalsa, wood apple), spices and condiments (arecanut, bettle leaf, black pepper, cardamom, cinnamon, dalchini, ginger, turmeric), and others (bamboo's, dhaincha, jute, sugarcane, tea, tree cotton) have been domesticated in India. In India 125 indigenous and 11 exotic species belonging to 23 genera have been found. More specifically, India is the second richest country of the world after China in terms of bamboo genetic resources. In total of 28 states in India, each is dominated by a specific type and/or variety of the crops (Figure 21).

Indian gene centre is a reservoir of vast plant genetic resources. It has provided valuable genetic materials for the development of genotypes resistant to biotic, abiotic stresses and for producing desirable plant type in crops like rice, wheat, pigeonpea, cucurbits and sugarcane. Exploration and germplasm collection is one of the primary activities of plant genetic resources management and it is systematized after the creation of the National Bureau of Plant Genetic Resources (NBPGR) in 1976.

Thus, to preserve the agricultural biodiversity, need of this hour is creating a supportive policy environment - including eliminating incentives for uniform varieties and for pesticides, and implementing policies for secure tenure and local rights to plant genetic resources - vital for agricultural biodiversity enhancement and for food security.

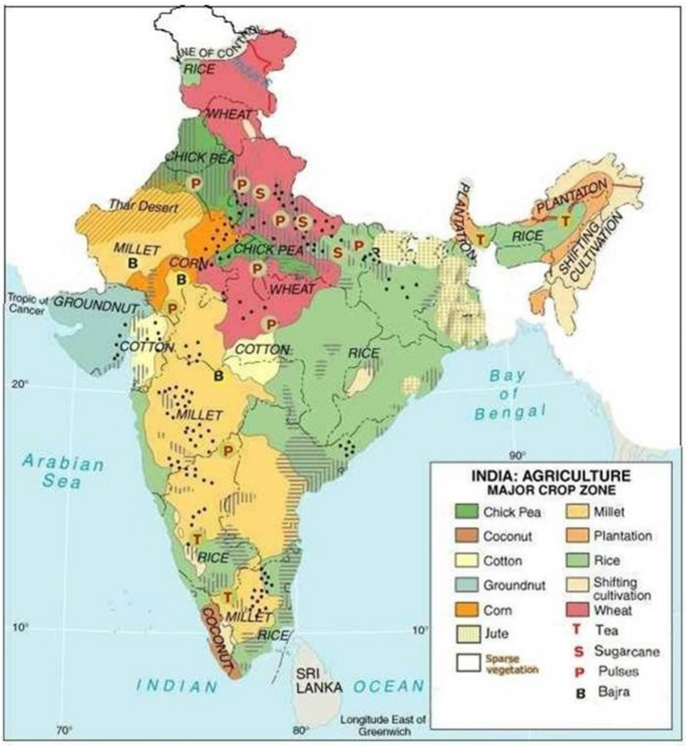


Figure 21: Biodiversity of agricultural crops in India (source: www.mapsofindia.com, 2013).

Biodiversity for medicinal application

Europe is the major trading centre for medicinal and aromatic plants globally having at least 2000 species originating from over 120 countries marketed.[92] The main challenges include unsustainable sourcing, environmentally-polluting practices, increasing costs and diminishing product pipelines. EU and national legislation attempt to regulate and mitigate these challenges generating a difficult commercial environment translated into increased costs, reduced profitability and ultimately the downsizing of the sector with direct negative social and economic consequences for society, such as the closure of R&D facilities, production plants, redundancies in the workforce and the transfer of business outside Europe. Therefore, bioprospecting on the diversity of plants may have a significant positive impact on European competitiveness in the plant biotechnology industry. The benefits to society at large will include the development of more affordable and biologically-relevant pharmaceutical products that can be produced safely and in large quantities, extending their accessibility to patients who may currently be excluded due to financial and other constraints. The biotechnology sector as a whole will be compelled to embrace sustainability as a business practice, which will encourage competitive research and the development of innovative production platforms based on plants. Such innovations are expected to promote the commercialisation of a wide range of secondary compounds without exploiting developing countries. These are all regulated at the EU level and combined expertise and investment is required to achieve final market approval. A pan-European approach to the research, development, market analysis, business environment, infrastructure requirements and regulatory outlook is therefore critical.

India is classified among world's 17 megadiverse nations with 2.4% of the land area, accounting for 7-8% of the species of the world, including about 91,000 species of animals and 45,500 species of plants that have been documented in its ten bio-geographic regions. Since ancient times, use of plants as a source of medicines has been the inherent part of life also in India. There are over 3000 medicinal plants in India. This list represents a 1000-odd plants which have been classified as traded medicinal plants according to the Environmental Information System (ENVIS) database. The ecosystems of the Himalayas, the Khasi and Mizo hills of northeastern India, the Vindhya and Satpura ranges of northern peninsular India, and the Western Ghats contain nearly 90 percent of the country's higher plant species and are therefore of special importance to traditional medicine.

For example the Indian trans-Himalaya harbours a relatively low number of species diversity but many of them are rare and endangered. Thus this area has been listed as the most ecologically fragile biogeographic zones in India. Some of the endangered and even critically endangered species that are used in traditional medicine in this area are listed in Table 11. [93] From biodiversity point of view it is thus crucial that sustainable harvesting is recognized as the most important conservation way of wild species and their habitats. The social and economic benefits from wild harvest particularly to the poorest members of society should be balanced so that the non-destructive harvest could maintain both local benefits and species diversity.

Table 11: Some examples of endangered medicinal plant species in Indian trans-Himalaya. [93]

Species	**Medical name**	**Plant part used**	**Uses**
Arnebia euchroma Johnston	Dimok	Root, leaves	Cough
Betula utilis D. Don	Takpa	Bark, leaves	Jaundice, burn
Dactylorhiza hatagirea (D. Don) Soo	Angbolakpa	Root, flowers	Aphrodisiac
Gentiana kurroo Royle	Pangyin	Flowers	Cough
Picrorhiza kurrooa Royle ex Benth	Honglen	Root, flowers	Fever, blood purification
Podophyllum hexandrum Royle	Tandik	Flowers	Blood diarrhoea

3.3 Strategy and Recommendations

Strategy

Europe & Member states

To achieve the goals stated in the vision taking into account the current status following strategies have been reported in this section.

Biomass and Biowaste production and use, and Biodiversity identification

Main Goals:

- Food security as priority, Non-food uses as additional opportunity; Sustainability in anything we do; reduce volatility (markets, climate)
- Increase and stabilize yield for food and non-food uses
- Multipurpose crops for bio-refineries (improve all parts of the plant by breeding and / or biotech as well for bio-refinery uses – in the past mainly for food uses)
- Sustainable intensification of agriculture and forestry (economic, environmental and societal issues)
- Reduce environmental impact of biomass production, protect the environment and regain abandoned land (e.g. improve soil fertility by cultivation of low-input, carbon sequestering perennial cropping), prevent desertification etc.
- increase resource use efficiency (breeding, co-cultivation/crop rotation/mixtures etc.)
- Ensuring that still sufficient part of organic matter remains on the field to ensure soil quality à what are the limits of biomass to remove and use for by-products
- Analyze and use biodiversity for i) choosing best adapted varieties in changing climate ii) making high value products

From [COM(2012) 79 final] "A shift towards a different growth path is needed in order to establish a competitive and sustainable production of plant biomass. It must include adaptation to climate change and the wise use of biodiversity and restoration of ecosystems and ecosystem services; it must build upon the particularities of each territory and the potential offered by genetic diversity so that we combine our rich genetic base with diverse agricultural practices, new and old, and ensure better allocation and use of our limited resources. Increased productivity and competitiveness of agriculture calls for improved resource efficiency, the increased use of renewable energy sources and a reduction of waste. Sustainability requires pollution reduction, the preservation of biodiversity and ecosystem services, as well as a reduction of greenhouse gas emissions. Solutions need to go beyond the individual farm and also integrate the broader geographical context, including forestry and nature reserves."

- Consumers / users can steer biomass production towards safety, high quality and sustainability
- Ensure greater farm profitability to support ecological sustainability
- Role of farmers in the supply chain must be strengthened

- Education and training: to change food consumption patterns, enhance nutrition and healthy lifestyles, to reduce food and other wastage, to accept new approaches of production
- Sustainability criteria, established at pivotal points throughout the supply chain, would contribute to increasing transparency, trust, and knowledge
- Minimisation of pre- and post-harvest losses (-> logistics chapter?)
- Develop efficient strategies to restore abandoned land, prevent desertification
- Farm structures (more agroforestry and mixed farming systems?)
- Change in land use patterns? (Distribution arable crops / livestock / slurry / manure etc. currently in part unfavorable)
- Towards higher resilience of production systems
- Change in farm practices (e.g. change crop rotation to enhance resource efficient production, adjust sowing dates according to temperature and rainfall patterns, use crop varieties better suited to new weather conditions (e.g. more resilient to heat and drought), …
- Appropriate technology, ICT and satellite navigation support, maps and forecasts (like MARS), new management tools
- [make better use of Biodiversity]; e.g. cultivation of higher-straw crop varieties
- [Breeding]
- Phenotyping
- Gap between provision of research results and application of innovative approaches to farming practice must be minimized

<u>India</u>

Challenges: The following important challenges need to be addressed in India:

- Continuous decline in availability of certified seed, fertilizer, water and land management

- Underused biomass potential (e.g. Rice biomass burning on field in Punjab)

- Lack of proper storage and processing capacity of materials (e.g. fruits and vegetables)

- Unawareness/underutilization of potential biomass resources (e.g. Algae, Seaweeds, Bamboo).

Strategies:

- Diversified agriculture, Agriculture intensification, Sustainable sharing of marginal farmers produce, Better storage, supply chain & logistics and Crop rotation are certain points which need to be immediately addressed in depth.
- A legislative MOU between success stories (R&D projects) and SRA.
- Emphasis should be given on state wise diversified crops with soil irrigation, certified seeds and better fertilizer etc.

Also regarding Indian biowaste situation, the only approach to deal with the waste since time immemorial, is dump it or burn it. However, these practices cannot be continued and should be replaced by developing long term solutions which will be beneficial to the environment, society and mankind. The main objective of the strategy is to minimize the hazardous effect of the wastes by processing and recycling from production to disposal and establishing bio-based economy. This approach also leads to the consideration of waste not only as a source of pollution but also as a potential source of bio-energy, to be explored. The main focus of the strategy is to promote the waste prevention and recycling sector to facilitate waste into economic cycle in the form of value added products. This requires a multidisciplinary approach in a coordinated way, to assess and understand the potential wastes and carry out their valorization in an environment-friendly manner.

Research Recommendations

Based on the State of the Art report and Biomass inventories elaborated under the Work package 2 & 4 of SAHYOG and a number of stakeholders consultations done during the various workshops and Bio-economy conference, organized under the framework of SAHYOG project, an online survey (http://www.sahyog-europa-india.eu/survey-eu-india-cooperation) was conducted on the research recommendations. Further lines of action are indicated in this chapter based on the recommendations made by a large number of stakeholders from EU and India, for further EU-India collaboration in the field of feedstocks production under three main biomass categories (Forestry, Agriculture and Wastes).

To set the bio-based economy value chain for the production of materials and energy in a sustainable way, it is strongly required to have a clear picture of the available potential of the biomass resources in Europe & and in India at the State level. Therefore, to get a clear picture of reliable and comparable data of the three biomass resource categories, it is strongly recommended to set up an appropriate and common methodology on the set templates for data collection in different countries. In particular, to this end the set-up of a common GIS-based biomass assessment method is necessary for biomass from forestry and agriculture. However, a prerequisite is a consensus on the definition of biomass potential for an accurate estimation of available biomass resources.

The following actions for future and research activities on Forestry, Agriculture and Waste biomass categories, are strongly recommended:

Europe & Member states

Forestry

As stated in the current status, a steady increase of the area covered by forests and other wooded land in the EU-27 has been observed over the past 20 years. Therefore,

- Inventory and forecasting including modelling and forest mensuration needs priority
- Research programs aimed at investigating adaptation to climate change, tree health, landscape ecology, biological sustainability and the interactions between woodlands and water, soil and wildlife are highly recommended
- Finally, aspects related to risk assessment, the effect on pests and pathogens, forest carbon and greenhouse gases needs detailed studies

Agriculture

Europe has limited land resources to cope with an increased demand for biomass for food and non food uses. Sustainable improvement of plant production implies the assessment of the environmental impact of biomass production. Therefore,

- Research should primarily focus on the development of high yielding dedicated energy crops and other crop varieties such as multipurpose crops providing by-products of interest for biobased economy value chain
- New tools and methodologies for modelling of cropping scenarios should be investigated
- Restoration of abandoned land with appropriate crops adapted to those soil and climatic conditions, needs particular attention
- Moreover, new technologies/methods for harvesting, collection and use of dedicated crops or other agricultural wastes is recommended
- Research on genomic and metagenomic approaches for identifying novel cellulolytic enzymes and secondary metabolite intensification is also recommended

- Biomass production intensification with sustainable inputs (water, bio-pesticides, organic fertilizers etc.) should be addressed for future research

Waste

The increasing appreciation of biowaste as a source of energy and valuable compounds coupled with the necessity to reduce pollution is leading scientific community to investigate the development of new routes to convert wastes (including solid waste) to a platform system for bioenergy and bio-based products. Therefore,

- Anaerobic digestion processes, in particular, aimed to obtain fuels and new valuable compounds should be improved to obtain high yielding safer conversion processes of wastes (including pretreatment and enzymatic hydrolysis)
- Development of efficient systems for the regular collection of household wastes
- Development and use of smart, economically and environmentally sustainable waste disposal technologies closer to the waste disposal cities

<u>India</u>

Agriculture

Implementation of traditional agriculture practices for intensified agriculture

- Optimization of tripartite approach: Soil quality determination-Selection of crop-Appropriate variety
- Comparative analysis of biofertilizers, biocontrol agents and chemical fertilizers
- Emphasis on traditional breeding approach for development of stress resistant varieties/ seeds (Abiotic and Biotic stress)
- Pilot scale project/programme for assessment of intermittent cropping and crop rotation system

Introduction of co-operative organization in agriculture sector for supply chain management

- Implementation of e-marketing system
- Internet Communication Technology (ICT) and knowledge transfer through panchayat

Assessment of shelf-life and storage of perishable foods/products to reduce post-harvest losses

- Assessment of door to door supply of marginal farmer's products involving small scale entrepreneurs
- Reliability on traditional storage facilities and their economic viability assessment

Procurement plan for zero waste

- Strategies for optimum utilization of agricultural residues/produces at different tier

Water harvesting/ conservation

- Improved practices for rain water harvesting and its utilization programme
- Detailed plan for better water conservation and management practices

Waste

Short term

Creating awareness towards the potential use of biowaste, amongst all the strata of society.

- Development of cost effective waste segregation and collection methods should be done
- Development of modules and awareness programmes for common people for segregated waste disposal by using media and advertising

To practicing systematic waste disposal approach

- Assessment of total number of villages, towns and cities and their respective municipalities and Urban Local Bodies should be done
- To implement systematic waste management, the types and amounts of waste should be assessed, and integrated waste treatment and disposal should be carried out
- Highly efficient and accurate technologies should be developed for waste collection and transportation
- Need to develop techniques to avoid large scale transportation

Segregation of waste needs to be done at the source level

- Technology to segregate waste and its efficient collection and transportation should be developed
- Training programmes should be organized for ragpickers and trash collectors to separate the different types of waste at the place of generation

Waste production should be minimized

- Using small scale biomethanation unit, locally produced organic waste can be used to produce biogas

- Development of more efficient digesters for biogas units
- Development of techniques for easier aerobic composting of kitchen and garden waste can be carried out
- Recycling of plastic waste can be done or it can be subjected to Refused derived fuel (RDF) production

Mid term

A new survey should be carried out to assess the generation and characterization of MSW and industrial waste in India. Since they are heterogeneous in nature, therefore a large number of samples have to be collected and analyzed to obtain significant results

- Creating local centres where amount and type of waste generated can be recorded This can be carried forward to larger centres where the waste is managed
- Techniques for yearwise survey on waste generation and future scenario of waste generated should be developed

Controlled and well managed dumping of waste to landfills needs to be emphasized to safeguard human and animal health

- A survey should be carried out to assess the harmful effects of landfilling to soil/environment/humans/animals
- Research on treatment/conversion of waste before landfilling, to minimize harmful effects should be carried out

Better and safer conversion processes should be developed to minimize the production of harmful by-products

- Research on development of enzymes and/or microorganisms that minimize the amount and toxicity of harmful by-products generated during the conversion of biowaste, should be promoted
- Genomics and metagenomics techniques should be utilized for identification of better cellulolytic enzymes
- The pathways and modes of action of enzymes should be investigated and modified, if required. Studies should be carried out to identify the effect of modifications on the genetics of microorganisms involved in the conversion of biowasteDevelopment of easier methods/pathways for conversion of lignocellulosic waste.
- Development of thermostable cellulases/hemicellulases will increase the efficiency foe waste conversion
- Development of pretreatment techniques like Ammonia Recycle Percolation (ARP), Ammonia Fibre Explosion and Steam explosion, for delignification can also be applied
- Development of techniques to use mixed culture of organisms for development of bio-plastics (recyclable plastics)

Long term

- Proper management system which involves public and private sectors through NGOs could improve efficiency
- Efficient solid waste management will lead to good public health and environmental benefits

Research recommendations for Europe & Member States and India

Based on the recommendations of EU and India, priority research areas for EU-India cooperation are :

- development of uniform databases for potential available biomass resources
- biomass production intensification with minimum and sustainable imputs of biofertilizers, biopesticides, water and selection of crops adapted to specific soil and climatic conditions
- optimization of crop harvesting and collection of agricultural wastes to reduce losses
- reduction of MSW landfilling through recycling of wastes
- development of efficient methodologies for waste collection, separation and treatment
- research and development of sustainable algae production systems for the production of renewable energy, wastewater treatment and for other uses

4. Bio-refineries

4.1. Vision

The replacement of oil with biomass as raw material for fuel and chemical production is an interesting option to reduce dependence on fossil fuels and is the driving force for the development of bio-refinery complexes. In our vision, Bio-refineries are highly energy-efficient and make use of mostly zero-waste production processes, and they allow industries to manufacture environmental friendly products with small carbon and water footprints. Therefore, a bio-refinery should be able to produce a gamut of marketable products and energy in a sustainable fashion. The products can be intermediates or final products, such as food, feed, materials, and chemicals; while energy includes fuels, power and heat. The design of a bio-refinery should be sustainable by taking into account possible unintended consequences such as the competition with food and biomass resources, water use, quality of the products, usage of land, emission of greenhouse gases and impact on biodiversity. Economic constraints dictate that bio-refineries need to be operated efficiently and at low cost. Due to the limited availability of biomass the raw materials should be used efficiently by developing multi-purpose bio-refineries. However, some have been established to exploit new value chains, such as aquatic/marine biomass.

The bio-refinery systems which will come into operation in the near future will have the production of biofuels (transportation sector) as the main focus[94]. These biofuels can be mixed with gasoline, diesel or natural gas to compensate the fuel scarcity in the transportation sector. The volume and the prices of these biofuels generated should be competitive with the fossil fuel prices in the future markets. Besides bio-refinery systems that are focused on producing energy carriers, in the longer term Bio-refineries will develop that are mainly producing biobased products and materials, with conversion of side streams to energy.

An open and collaborative approach creates synergies in education, research, development and innovation throughout the bio-refinery value chain. Integration of supply and manufacturing chains and increased collaboration between innovative players from traditional industries such as the chemical, energy, agriculture and forestry sectors combines the key strengths of each sector, creating the critical mass to attract investors, policymakers and young talent. Therefore a key factor for the development of a sustainable, highly efficient and cost effective bio-refinery is the integration of aforementioned parameters into the existing infrastructure. At national, regional and global levels there are three main drivers for using biomass in bio-refinery for production of bioenergy, biofuels and biochemicals. These are *climate change, energy security and rural development*. The political motivation to support renewable sources of energy and chemicals arises from each individual driver or combinations. Policies designed to target one driver can be detrimental to another. For example, policies aimed at ensuring energy security may result in increased *Green House Gas* (GHG) emissions where local coal reserves are preferentially exploited at the expense of imported oil or gas. In addition, electricity and heat can be provided by a variety of renewable alternatives (wind, sun, water, biomass and so on), while biomass is very likely to be the only viable alternative to fossil resources for production of transportation fuels and chemicals, since it is the only C-rich material source available on the Earth, besides fossils. As a consequence, the sustainable biomass production is a crucial issue, especially concerning a possible fertile land competition with food and feed industries[95].

Biorefineries in the future…

The design of a biorefinery should be sustainable by taking into account all the possible unintended consequences viz., competition between food and biomass resources, water use, quality of the products, usage of land, emission of greenhouse gases and impact on biodiversity

In conclusion, the development of bio-refineries should be steered towards development and implementation of bio-refineries that can deal with **multiple biomass feedstock streams** either via a single process or through a combination of several integrated ones: flexibility is very important. Furthermore, economic constraints dictate that bio-refineries need to be operated **efficiently and at low cost**, and (further) adoption of **sustainability criteria** will drive the continued development of Bio-refineries. The development of more flexible and sustainable bio-refineries in the future will only be possible if crucial bottlenecks along the value chain can be removed. In this strategic research agenda, a number of these bottlenecks will be identified, while listing solutions in order to overcome them.

4.2. Current Status

Introduction

By producing multiple products, a bio-refinery can take advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock. A bio-refinery might, for example, produce one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and perhaps enough for sale of electricity. The high-value products enhance profitability, the high-volume fuel helps meet national energy needs, and the power production reduces costs and avoids greenhouse-gas emissions[96]. Bio-refinery industries are expected to develop as dispersed industrial complexes able to revitalize rural areas. Unlike oil refinery, which almost invariably means very large plants, bio-refineries will encompass a whole range of different-sized installations. In this context, several bio-industries can combine their material flows in order to reach a complete utilization of all biomass components: the residue from one bio-industry (e.g. lignin from a lignocellulosic ethanol production plant) becomes an input for other industries, giving rise to integrated bio-industrial systems. Biomass energy is considered as one of the most promising sources of renewable energy in India. Refining biomass for biofuels and byproducts has enormous potential in the region due to the wide availability of feed stocks and access to vast areas of land and sea. India's large rural workforce can increase the possibilities for enhancing energy security and subsequently reduce GHG emissions. Government agencies involved in the biofuel industry should coordinate to form a holistic view of the value chain i.e. regional governments should harmonize their strategies regarding policy. Such coordination would decrease the risks inherent in investing in the renewable energy industry[97].

It is noted that since 2002, India has increased its share of electricity produced by renewable sources from 2% to approximately 13%, illustrating the positive effects of government incentives on green power. Subsidies for non-renewable sources, however, hinder the economic viability of research into land and ocean bio-products at present.

Currently, the research is focused on various aspects of bio-refinery for a sustainable future. Research on the technology development for the ease of bio-based product preparation such as flexibility of input, Process capabilities and product generation, is in focus today.

Several researches around the world are looking into the best sources for utilizing in the energy production process. Utilizing the waste from food industry as a source for renewable carbon is adding on a new direction to the food industry. Food industry wastes like wheat straw contains high value wax compounds such as fatty alcohol, alkanes etc. Lignocellulosic fractions are being used to produce ethanol and paper. The rice husks are burned to produce energy which can drive the machinery in the farm[98]. The traces are rich of silica, which are also being used as an end product. Food oils for bio-diesel and glycerol production and gasification of food waste to drive gas turbines resulting in electricity production are some of the current benefits obtained from the waste of food industry. Along with food industry waste, several other industries wastes (pharmaceutical, ink, paper and pulp etc) are being dealt for the production of renewable energy.

Current status of Bio-refineries in Europe

The EU is major player in international trade in agricultural commodities and food. EU is by far the world's largest importer, although its share of total world imports is in decline. The EU agriculture largely based on family farming. The sector supplies materials for starch, sugar and biofuel production[99]. Currently, the European starch industry produces starch from maize, wheat and potatoes for a variety of applications including native and modified starches, starch saccharification products (e.g. syrups), and by-products of starch production for animal feed. The European sugar industry produces crystallised sugar, liquid sugar feed, byproducts for animal feed, and alcohol. Overall, the EU sugar production has been in decline in the past decade. The oilseed industry in the EU is based on production of rapeseed, sunflower and (imported) soybean, and produces food and feed ingredients, oleochemicals, biodiesel, and animal feed. The oilseed industry heavily relies on imported feedstocks from other regions in the world. In the EU, the forest products sector representes 8% of total economic value of the manufacturing industry, and provides 3 to 4 million jobs. Main products from this sector are furniture and construction materials, paper, bioenergy, and wood-based chemicals. Currently, integrated pulp and paper mills can be considered as the best examples of wood-based bio-refineries. The European energy sector (heat and electric power) is a very large sector with more than 20,000 companies in the sector that provide > 12 million jobs. Main products are electricity, natural gas and hot water. The use of biomass in this sector is heavily affected by bioenergy targets set by the European Commission. The Biofuels industry in the EU provides liquid biofuels for transportation in the order of 14 million tons of oil equivalent. Main products are fatty acid methyl esters (FAME) from oilseeds, and ethanol from wheat, barley and sugar beet and alongside a number of byproducts for animal feed are produced. Minor products are biogas and pure vegetable oil.

The European Commission has adopted legislation to limit to the production of so-called first generation biofuels, and a number of pilot and demonstration projects for advanced biofuels are in progress. Finally, the Chemical industry produces amino acids, lipids, organic acids, and vitamins for application in food, feed, detergent and cosmetics. To date, most production is based on sugars, starch, or vegetable oils. A number of new biobased platform chemicals such as 1,3 propanediol and succinic acid are of interest. There is a small but growing bioplastics industry in the EU.

Current status of Bio-refineries in India

Currently, there is no integrated overview of Bio-refineries in India. However, a number of important agri-industries exist in India that could be either viewed as (early) bio-refineries, or could develop as bio-refineries in the future. These industries include the Indian sugar cane milling industry, rice and wheat milling sector, the pulp- and paper industry, as well as the bamboo industry

Sugar Industry in India

In the 2011-2012 season, some 529 sugar mills were in operation, that used sugar cane from about 5.1 Million ha. The total sugar production was estimated at 26.3 M tons, and 11.8 M tons of molasses. Total ethanol production capacity per year : 2.073.600 cubi meters ethanol per year, with production in Karnataka, Gujarat, Maharashtra, Tamil Nadu, Andra Pradesh, Uttar Pradesh, and Bihar. Production is affected by the 5% mandatory ethanol blending policy.

Sugar mills in India consume their own bagasse to run their mills during the season and generate steam to run the boilers and turbines; they generate power to run their plants. Surplus energy can be exported to the grid of distribution licensees. The Central Electricity Regulatory Commission (CERC) is the central body which regulates the various aspects of generation and supply system at national levels. Besides CERC, there are State Regulatory Commissions in each and every State to deal with the aspect of tariff and regulation of generation, supply and distribution of energy. According to ISMA, no State has so far allowed open access, electricity cannot be exported outside the State. A total of 3221 MW cogeneration capacity is used in the crushing season, whereas in the off-season, 732 MW of capacity is used. More statistics on the Indian Sugar milling industry are available from www.indiansugar.com

Rice milling industry in India

According to the FAO statistics India is the second largest producer of rice (after China). The Rice production in India is mainly consumed within India itself. According to the statistics of the All India Rice Exporters Association (AIREA), India produced 80 million tons of rice in the season 2010-2011 [100] from which 2.5 million tons was exported[101] . Uttar Pradesh, Punjab, Andra Pradesh and West Bengal are the states with the highest production quantities. Together they produce half of all the rice produced in India, see table. There are more than 35000 Rice mills in India[102] .

The mills produce different types of rice and in the cleaning process rice husk and rice bran are separated. 20% of the incoming rice paddy is separated as husk for the 2010-2011 season that is more than 20 million ton, a huge load of biomass. Until recently this was a waste , but since 2007 an Indian company called Husk Power Systems has built 80 small power plants of 35-100kW in rural areas that use rice husks instead of fossil energy. The systems provide electricity to over 200,000 people across 300 villages and hamlets. It saves 30% of the consumers costs for kerosene and diesel and each plant helps avoid 125 to 150 tonnes of CO2 per year. The company has identified many thousands feasible locations for building these plants and has won several business prizes[103].

Gidde reported that there are many uses of rice husk like fuel, building materials and polishing agent, however only a small portion of the yearly 24 million tonnes of husk is used. Rice Hull Ash (RHA) can be used in high performance concrete and can replace silica fume that has reached prices of US$ 500 / ton in India[104].

Straw is another byproduct of the rice cultivation. The company Bermaco is setting up large straw-fired biomass-based power plants of 12 MW each. The potential in Bihar is 26 plants with a total of 312 MW and 9 power plants in Punjab with a total of 108 MW. The allied Punjab Renewable Energy Systems Pvt. Ltd. (PRESPL), bridges the gap between Power Plant and Fuel as an input to the Plant. The Company has successfully managed huge logistics of fuel collection and storage. It is handling supply of around 700 MT of biomass from sources as paddy straw, cotton stalk, maize cob and bagasse on a daily basis.

Pulp and paper Industry in India

The pulp and paper industry is small compared to the rice industry. According to the FAO estimates of 2012 India produced 2.3 million tons of wood pulp and 0.5 million tons of recovered paper. India imports 1 million tons of wood pulp and 2.3 million tons of recovered paper. The export of wood pulp is only 2000 tons. The production of other fibre pulp was 2 million tons. The total production of paper and paper board is 10.2 million tons. The import of paper and paperboard was 2.2 million tons and the export counted 3.4 million tons.

The use of recycled paper as a raw material is increasing. In the period 2000-2011, the share of recycled in the different raw materials increased from 30 to 47% material in the 2011. The shares for wood dropped from 39 to 31% and those for agro-based fibre from 31 to 22%. Most of the large pulp and mills use wood as raw material and have modern production processes like cogeneration and recovery plants and produce good quality papers. The agro-based mills are in general small and use old technologies without recovery plants and pollution control, resulting in high pollution loads and low quality paper.

Abishek Pulpmill of the Trident company shows that an agro-based pulp mill can be environmentally sound. It is a modern pulp mill that is one of the biggest mills based on wheat straw. It has a capacity for 225 t/day of straw pulp and 125 t/day of wood pulp creating a total capacity of 350 t pulp/day. The raw material mix for pulp making consists of 60 % agro residuals, 30 % hardwood (Eucalyptus) and 10 % imported softwood (Pine). The Abishek pulp mill has modern pulping and recovery technologies with low fresh water use and low emissions[105].

The Pulp & Paper industry is the seventh highest energy consumer in India. Many mills use very high amounts of energy compared to modern mills. The energy forms a large component in the production costs. In 2007-08, this industry used about 5.49 % of total coal and 2.50 % of total electrical energy. It also consumed 2.33 % of total petroleum products and about 3.22 % of other types of fuels utilized by whole manufacturing sector. The intensity of energy consumption expressed as fuel consumption per unit of value produced is decreasing since the year 2000 as a result of higher energy prices which led to savings in energy use and cogeneration of power.

Modern mills like the Abishek mill, can be seen as a part of a bio-refinery system. It uses straw that is a by-product of wheat grain production, chemicals are recovered and dissolved material (mainly lignin) is used as an energy source. Worldwide a lot of research is applied on the separation and utilisation of the dissolved lignin which can add more value to it than use as an energy source. If feasible applications are found, the bio-refinery concept might be further developed an diversified in the future[106].

Bamboo industry in India

Bamboo can be used for many products like paper, textiles, panels and boards and young bamboo shoots as food.

Data from the India State of Forest Report, 2011 show that with 14 million hectares of bamboo India is the second largest producer of bamboo in the world. Only 15% of that area is private property. The estimated total weight on that area is 169 million tons of which 73% Green sound bamboos and 27% dry sound bamboos. Arunachal Pradesh, Assam, Manipur and Mizoram have the highest numbers of bamboo culms. Aniket Baksy studied the use of Bamboo for high and medium value products like flooring, furniture and mat boards by domestic industries. Plenty of Bamboo resources are available for these products however firms nonetheless must import Bamboo for their products. It is estimated that the quantity of Indian imports of Bamboo Poles in 2012 was approximately 6.1 Million kg, valued at US$ 5.62 Million. The import of Bamboo plywood, veneered panels & similar laminated wood was only 29000 kg only 0.5% of that of the imported bamboo poles however the value of this processed bamboo was 2.5 times higher. This shows how high the added value can be by processing the bamboo in products. The total value of all exported bamboo products was only 9% of the imported value. Aniket Baksy concludes that this type of industry is in an infant stage and proposes specific actions to develop this type of industry[107].

India is eager to learn about the tools and technologies from China how to develop such industries. In 2011 Trade& Exposure Delegation Trip to China on Bamboo Technology. China has achieved very good results in bamboo plantation management and integrated processing with a total value 9 billion US$[108].

In February 2014 the Bamboo Society of India together with many other parties organized the International Bamboo Conclave & Expo- with the aim to bring awareness, promote and realize the use of bamboo in the construction industry[109].

Bamboo is used in the pulp and paper industry, charcoal industry and bamboo scaffolding. According to the National Bamboo Mission (NBM) 20% and 24% of harvested Bamboo are respectively used by the paper and pulp industries, and for scaffolding. A good overview of the industrial usage of bamboo could not be found. That makes it difficult to find industrial bio-refinery applications of bamboo. Of course in the production of pulp and paper from bamboo, the same use of residues as described in the paragraph on Pulp and paper Industry can be practiced in India.

Feedstocks for Bio-refineries

Renewable carbon-based raw materials for bio-refinery are provided from four different sectors: Agriculture (dedicated crops and residues), Forestry, Industries (process residues and leftovers), households (municipal solid waste and wastewaters), and Aquaculture (microalgae and seaweeds).

The main biomass feedstocks can be grouped in three wide categories: carbohydrates and lignin, triglycerides and mixed organic residues.

Carbohydrates and lignin: Carbohydrates (from starch, cellulose and hemicellulose) are molecules of carbon, hydrogen, and oxygen and are by far the most common biomass component found in plant feedstocks. Six-carbon, single-molecule ‘‘monosaccharide” sugars ($C_6H_{12}O_6$) include glucose, galactose and mannose, while the most common 5-carbon sugars ($C_5H_{10}O_5$) are xylose and arabinose. The two most important sugar crops are sugar cane and sugar beet which, together with corn (a starch crop), supply almost all the ethanol that is produced today[110]. Lignocellulosic biomass has three major components: cellulose, hemicellulose and lignin. Cellulose $(C_6H_{10}O_6)_n$ has a strong molecular structure made by long chains of glucose molecules(C_6sugar). Lignocellulosic biomass can be provided either as a crop or as a residue. Large amounts of cellulosic biomass can be produced via dedicated crops like perennial herbaceous plant species, or short rotation woody crops. Other sources of lignocellulosic biomass are waste and residues, like straw from agriculture, wood waste from the pulp and paper industry and forestry residues. The use of waste biomass offers a way of creating value for society, displacing fossil fuels with material that typically would decompose, with no additional land use for its production[111].

Triglycerides: Oils and fats are triglycerides which typically consist of glycerine and saturated and unsaturated fatty acids (their chain length ranges between C8 and C20, but 16, 18 and 20 carbons are the most common). The sources of oils and fats are a variety of vegetable and animal raw materials. Soybean, palm, rapeseed and sunflower oil are the most important in terms of worldwide production [112] [113]. Like sugar and starch crops, oilseed crops are characterized by low yield and high use of inputs. In the future, non-edible crops like *Jatropha curcas* and *Pongamia pinnata*, which require lower inputs and are suited to marginal lands, may become the most widespread oil crops for bio-refinery purposes, especially in dry and semiarid regions[114]. Other sources of vegetable oil for biofuel conversion can be found in waste streams of food industry, where waste edible oil is mainly generated from commercial services and food processing plants such as restaurants, fast food chains and households[115].

Mixed Organic Residues: Other types of biomass sources that do not fall within the previous categories are organic fraction of the Municipal Solid Waste (MSW), manure, wild fruits and crops, proteins and residues from fresh fruit and vegetable industries. The physical and chemical characteristics of this wide spectrum of biomass resources vary largely. Certain streams such as sewage sludge, manure from dairy and swine farms and residues from food processing are very wet, with moisture contents over 70%. Therefore, these feedstocks are more suited for an anaerobic digestion process to generate biogas, rather than other fuels or chemicals. Other streams, such as organic MSW, may be more or less contaminated with heavy metals or other elements, but represents a high potential for energy recovery[116].

In the EU, biomass and biowaste account for 66 % of the total renewable energy consumption (98 million tons oil equivalent (Mtoe) in 2008), or 5 % of the total energy consumption. Solid biomass represents the main share of this (70 Mtoe), with the rest provided by biogas, transport biofuels and organic, solid municipal waste. It is now also widely recognised that biomass as feedstock for conventional and advanced biofuels competes with a number of other end uses (feed, food, paper, wood products, biomaterials, heat, electricity, etc.). The production of biomass may also be complementary to other uses. Recent debates over 'food or fuel' have led to an increasing interest in biomass from waste and residues as biofuel feedstock. Moreover, the focus in biofuel support is shifting from simple volume production to GHG saving, making waste materials all the more favourable. The use of advanced biofuels or those from residues and wastes is expected to reduce feedstock demands, in the case of the former due to higher net fuel yields per hectare, and in the case of the latter because fuel derived from organic wastes is counted double under the RED. The RED gives residual feedstocks and wastes (agricultural, forestry, industrial and municipal) an advantageous profile, as they provide GHG emission savings without competing for finite land resources. Furthermore, growth continues in local trade of unrefined feedstocks, such as wood pellets and vegetable oils.

Technological processes in Bio-refinery

The aim of technological process in bio-refinery is de-polymerizing and deoxygenating the biomass components. In order to convert biomass feedstock into valuable products within a bio-refinery approach, several technological processes must be jointly applied. They can be divided in four main groups: thermochemical, biochemical, mechanical/physical and chemical processes.

Thermochemical processes: There are two main thermochemical processes for converting biomass into energy and chemical products. The first is gasification, which consists in keeping biomass at high temperature (>700^{o}C) with low oxygen levels to produce syngas, a mixture of H_2, CO, CO_2 and CH_4[117] [118]Syngas can be used directly as a stationary biofuel or can be a chemical intermediate (platform) for the production of fuels (FT-fuels, dimethyl ether, ethanol, isobutene...) or chemicals (alcohols, organic acids, ammonia, methanol and so on). The second thermochemical pathway for converting biomass is pyrolysis, which uses intermediate temperatures (300-600^{o}C) in the absence of oxygen to convert the feedstock into liquid pyrolytic oil (or bio-oil), solid charcoal and light gases similar to syngas [119120121]. Anaerobic digestion involves the bacterial breakdown of biodegradable organic material in the absence of oxygen over a temperature range from about 30 to 65^{o}C. The main end product of these processes is biogas (a gas mixture made of methane, CO_2 and other impurities), which can be upgraded up to >97% methane content and used as a surrogate of natural gas[122].

Mechanical processes are processes which do not change the state or the composition of biomass, but only perform a size reduction or a separation of feedstock components. In a bio-refinery pathway, they are usually applied first, because the following biomass utilization requires reduction of the material size within specific ranges, depending on feedstock species, handling and further conversion processes. Separation processes involve the separation of the substrate into its components, while with extraction methods valuable compounds are extracted and concentrated from a bulk and inhomogeneous substrate[123]. Lignocellulosic pre-treatment methods (e.g. the split of lignocellulosic biomass into cellulose, hemicellulose and lignin) fall within this category, even if some of hemicellulose is also hydrolyzed to single sugars[124].

Chemical processes are those processes which carry a change in the chemical structure of the molecule by reacting with other substances. The most common chemical processes in biomass conversion are hydrolysis and transesterification, but this group also includes the wide class of chemical reactions where a change in the molecular formula occurs. Hydrolysis uses acids, alkalis or enzymes to de-polymerise polysaccharides and proteins into their component sugars (e.g. glucose from cellulose) or derivate chemicals (e.g. levulinic acid from glucose). Transesterification is the most common method to produce biodiesel today and is a chemical process by which vegetable oils can be converted to methyl or ethyl esters of fatty acids, also called biodiesel. This process involves the coproduction of glycerine, a chemical compound with diverse commercial uses[125]. Other important chemical reactions in bio-refining are Fisher-Tropsch synthesis, methanisation, steam reforming, among others.

Unlike thermochemical processes, **biochemical processes** occur at lower temperatures and have lower reaction rates. The most common types of biochemical processes are fermentation and anaerobic digestion. The fermentation uses microorganisms and/ or enzymes to convert a fermentable substrate into recoverable products (usually alcohols or organic acids). Ethanol is currently the most required fermentation product, but the production of many other chemical compounds (e.g. hydrogen, methanol, succinic acid, among others) is nowadays object of many research and development activities.

Classification of Bio-refineries

The four main components of a bio-refinery are:

1. Platforms (e.g. core intermediates such as C5-C6 carbohydrates, syngas, lignin, pyrolytic liquid)

2. Products (e.g. energy carriers, chemicals, biogas in the form of hydrogen and methane, energy in the form of bioelectricity and material products)

3. Feedstock (i.e. biomass, from dedicated production or residues from forestry, agriculture, aquaculture and other Industry and domestic sources including waste/ wastewater derived from various industries and polluted water bodies)

4. Processes (e.g. thermochemical, chemical, biochemical, biocatalyzed and mechanical processes)

The bio-refinery process chain consists essentially of system components for the pre-treatment and preparation of biomass, as well as for the separation of biomass components (primary refining) and the subsequent conversion/processing steps (secondary refining)[126]. The numerous examples and variants for all of the promising bio-refinery concepts are given below.

A full overview of the different Bio-refineries, including platform type, raw materials and primary and secondary refining steps is presented in Table 1 .

Table 1 Classification of Bio-refineries

Biorefinery type	Platform	Raw materials	Primary Refining	Secondary Refining/ Products
Sugar Biorefineries	Sucrose constitutes the major platform of the sugar bio-refinery. In a sugar bio-refinery the primary refining results in sucrose commonly known as sugar.	A variety of plants can serve as raw materials for sugar production. The most important sugar-producing plants worldwide are sugar cane and sugar beet. The sugar beet forms a root body, which stores the sugar in the growing season from spring to late September. The plant is harvested from September to November. The sugar beets are transported to	The primary refining is divided into juice production, juice purification, juice thick-ening and crystallization. For the juice extraction, the washed beets are crushed in cutting machines. The cuttings are heated to 70°C and turned into slurry in a vessel with an agitator. The sugar is then extracted and extraction towers, where the cuttings are de-sugarised with hot water in a counter-current process. The extracted cuttings are dried and used as animal feed. As well as sugar, the raw juice from beet extraction also contains non-sugar materials. The raw juice is mixed with lime water for purification. Together with the non-sugar materials, the excess calcium carbonate is then precipitated and used as fertilizer. The filtrate is a clear, pale yellow, thin sugar juice, which is then	Most part of the sugar syrup is processed into sugar, but can also be used as a fermentation raw material (e.g. for bioetha-nol, chemical intermediates). Granulated sugar is used as table sugar in the food industry, or finds application in the commercial sector. It serves as a fer-mentation raw material or can be used as precursor for chemical intermediate or finished products (e.g. surfactants). Molasses is utilized as raw material (for instance as feed yeast, bioetha-nol, chemicals), for the production of feedstuffs and fermenta-tion processes. Molasses can also be further de-sugarized for the production of crystalline sugar. Along with sugar, molasses also contains other ingredients (organic acids, betaine, vitamins and inorganic salts), which can be isolated and further processed. The chemical intermediates or fermentation products (e.g. amino acids, lactic acid, citric acid, glu-conic
Starch Biorefineries	In a starch bio-refinery, primary refining results in starch, constituting the platform of starch bio-refinery.	A variety of plants can serve as a raw material base for starch production. The most important starch crops worldwide are cereal crops (corn, wheat, rice), potatoes and cassava. In corn and wheat, the starch is contained in the grains, while in potatoes the starch is con¬tained in the tubers.	The first processing step for the cereal grains is the soaking and expansion of the grains (where appropriate after grinding) followed by germ separation, grinding and sieving. Then the starch is dissolved and fibers as well as protein are separated. The starch slurry is then cleaned and dried to obtain pure starch. The extraction of starch can be carried out using either local grains, potatoes or imported grain. Native potato starch, wheat starch or corn starch can be used as raw products for further processing into bio-based products and/or the production of bioenergy. The separated proteins and fiber residues are incurred by-products.	Native starch is used in the food and chemo-technical industries, where it is either directly further processed or converted to starch modifications and starch saccharification products. Chemotechnical utilization is the manu¬facturing of paper and cardboard, the further processing into chemo technical products (e.g. adhe¬sives) and the manufacturing of finished products (e.g. tyres). Native starch is modified chemically or physically for the production of starch modifications. The resulting starch modifications (e.g. starch esters, starch ethers, dextrins) and starch mixtures are then further processed for use as thickening agents in the food industry, as an additive in paper produc¬tion, or as an intermediate product in the cosmetics industry. Starch saccharification products (e.g. dextrose, glu¬cose) result from the degradation of the pol¬ymeric starch into low molecular weight products. The hydrolysis of starch provides three product groups that differ in their degree of hydrolysis and which are used as feedstock for the production of other starch sugar derivatives: Maltodextrins (starch hydrolysates with a DE content of less than 20), glucose syrup (starch hydrolysates with DE content of more than 20 and less than 80), dextrose syrup (starch hydrolysates with DE content of more than 80). These three product groups are either utilized directly or are further processed. . The corn protein gluten can be used as a binder and adhesive in the food industry and in the chemo-technical area. The separated fiber residues are commonly used for animal feedstuffs.

Table 1 (cont)

Biorefinery type	Platform	Raw materials	Primary Refining	Secondary Refining/Products
Vegetable oil Biorefinery	In a vegetable oil bio-refinery, the compo-nent separation in the primary refining produces vegetable oil, which constitutes the platform for the vegetable oil bio-refinery.	The precursors for the production of vegetable oil are oil seeds and fruits, whereby oil is present together with other lipids. The most impor¬tant oil seeds worldwide are rape seed, soybeans, sunflower seeds, cottonseed and peanuts. The most significant global oil crops are oil palm fruit and kernels, coconuts and olives. Rape is by far the most important oil plant and linseed and sunflowers are also cultivated over large areas. The selection of raw materials is also influenced by the intended products. Short-chain and long-chain fatty acid content is of particular signifi¬cance for later application.	The oil-containing seeds or fruits are cleaned and shredded. The vegetable oils are then separated by pressing (cold or hot) or by extracting (in rare cases by centrifugation). The extraction of vegetable oils that serve as a source of short-chain fatty acids generally takes place in the tropical countries of origin. The extraction of vegetable oils that serve as a source of long-chain fatty acids proceeds using both domestic oilseeds (rapeseed, sunflower seeds, linseed) as well as imported oil seeds and fruits (e.g. soybeans). Crude vegetable oil (fats and oils) is available as a raw product for further processing. Meal extract or press cake are obtained as co-products which can be used as oil seeds.	The vegetable oil can be used either in the food area or in the technical area. In the technical area, native vegetable oil is either used in virgin form (or following transesterification in the form of biodiesel) as a fuel or for the production of electricity and heat, e.g. combined heat and power plants (CHP). The native vegetable oil is purified before utilization or further processing. On the other hand, vegetable oil is a valuable raw material for the oleo chemical industry or for the production of lubricants. Vegetable oil can be used directly (e.g. as a sol¬vent) or is cleaved to obtain fatty acids and glycerol. In turn, fatty acids are precursors for a whole raft of chemical products and can be found in cosmetics, surfactants, lacquers and dyes and among other products after processing. Glycerin also has a wide range of applications; further processing produces pharma¬ceutical grade glycerine, and subsequent conversions and chemical reactions provide further chemical in¬termediates and products. Glycerol can also be used as a fermentation raw material. In turn, the fermen¬tation products are either chemical intermediates or are further processed into finished products. A technical utilization or combustion of co-products, meal extract or press cake would be possible in principle, but utilization as feedstuff produces more value, and in the case of livestock production (above all through use as manure) makes a contribution to the closing of the nutrient cycle on the field.
Algal lipid Biorefinery	In an algal lipid bio-refinery, component separation in primary refining results in algal lipids and algal biomass, which constitute the platform of the algal lipid bio-refinery.	The precursor in the production of algal lipids is microalgae. Microalgae are single or few-celled creatures that conduct photosynthe¬sis but do not belong to the actual plant. They are found in saltwater and freshwater. Upon arresting of growth i.e. via lack of nitrogen with simultaneous supply of CO2 and light, many microalgae are known to become enriched in lipids in the form of oil drop¬lets in the cells.	The wet, oily algal biomass is con¬centrated to 15-20% bio dry matter content through the separation of water and algal biomass via centrifugation, flocculation or filtration. Depending on the strain and the extraction method, the algal biomass must undergo decomposition, using a high-pressure homogenizer or bead mill. Microwaves or ultrasound can be used to directly support extraction, if required. The degraded, wet algal biomass must be dried. After dry¬ing (spray-drying) the algal biomasses are storable. Today, algae oil is extracted from previously dried and degraded algae biomass using a variety of solvents, the best results being achieved with hex¬ane. An advantage of the use of supercritical fluids for extraction is that neither the crude algal oil nor the residual biomass contains any solvent residues that could interfere with further processing. The solvent is separated and fed back to the process. Algal lipids (algae oil) and the largely oil-free algal biomass are available as a raw product for further processing.	Alongside triglycer¬ides and polar membrane lipids, the algae crude oil contains other lipophilic algae ingredients such as carotenoids, chlorophyll and phytosterols, which can be selectively extracted and modified in second¬ary refining. The triglycerides can be used either in the food industry or in the technical area. In the later case, it can be directly used as a fuel for CHP, conversion through processes like hydroprocessing to green naphtha (C5-C10), green jet fuel (C11- C13), and green diesel (C14- C20), and even green liquid petroleum gas (LPG) and transesterification to biodiesel [25]. Triglycerides are also a potential raw material for the chemical in¬dustry. In the chemo-technical area, triglycerides can be used directly, or fatty acids and glycerol extracted via cleavage. In turn, fatty acids are precursors for a whole raft of chemical products and after process¬ing can be found in cosmetics, surfactants, lacquers and dyes, among other products. Glycerol also has a range of applications: Further processing produces pharmaceutical grade glycerine or chemical intermediates and products. Glycerol can also be used as a fermentation raw ma¬terial. The fermentation products are either chemical intermediates or are further processed into finished products. After drying, high-protein feedstuff is produced using the de-oiled algae biomass or the algal biomass can be converted as co substrate into biogas through anaerobic decomposition.

Table 1 (cont)

Biorefinery type	Platform	Raw materials	Primary Refining	Secondary Refining/Products
Lignocellulosic biorefinery	In a dry-biomass-based lignocellulosic bio-refinery, the component separation in the primary refining produces the lignocellulosic components such as cellulose, hemicelluloses and lignin, which thereby constitute the platform for the lignocellulosic bio-re¬finery.	Lignocellulosic biomass as a raw material can be derived from a variety of sources, such as agricultural residues (e.g. straw, bagasse, and corncobs), energy crops (e.g. annual and perennial grasses), wood and biogenic waste (e.g. paper waste). For reasons of quality and quantity-related availability, agricultural residues (cereal-and corn straw) and woody biomass residues (forest wood, poplar short rotation wood) are significant. However annual and perennial grasses might also play a role in the future.	The pre-treatment of the lignocellulosic biomass is essential and initially entails a mechanical process step (milling or grinding). Decomposition is conducted by means of pressure and temperature, with or without chemical agents. Decomposition can alternatively be conduct¬ed by means of concentrated acid. The lignin can be separated either by extraction during pre-treatment or from the remaining solution as an insoluble component. Depending on the mode of decomposition, cellulose, hemicelluloses and lignin are available for further processing as raw materials.	(a) Mostly cellulose and hemicelluloses fractions are used in the production of fermentable carbohy¬drates. The enzymatic conversion into correspond¬ing monomeric carbohydrates (e.g. glucose, xylose) results in one material flow of fermentable sugars and one material flow of lignin. The fermentable sugars can be sent directly to biotechnological production, such as the production of ethanol and other higher-chain alcohols, biopolymers, organic acids, amino acids or other biotechnological prod¬ucts. (b) The cellulose, hemicellulose and lignin fractions are processed separately via isolated processing. Depending on the objective of the decomposi¬tion, the cellulose obtained in decomposition can be processed into paper or chemical pulp or, after enzymatic hydrolysis, processed into glucose as a fermentation or chemical raw material. The sepa¬rated hemicellulose fraction contains more or less decomposed carbohydrates and various monomeric C6 and C5 carbohydrates. From this, monomeric carbohydrates (e.g. xylose) can be separated and then refined, for example by fermentation or chemical methods. Through the degradation of the original hemicelluloses, the separated hemicellulose fraction contains a range of other useful substances (e.g. ace¬tic acid, furfural), which can be extracted and further processed in the chemo-technical section. On the other hand, with its aromatic structure, lignin offers the possibility of (selective) degradation to monomeric and dimeric aromatic compounds (e.g. phenols). An alternative possibility is the use of lignin and/or a lignin/hemicellulose solution for energy production. This can be carried out either by incineration or by gasification.
Green Biorefinery	In a green bio-refinery, component separa-tion in primary refining results in press juice and cellulosic fibers, which constitutes the major platform of the green bio-refinery.	Moist biomass in green or ensiled form, such as annual and perennial grasses and cere¬als is used as raw material in green bio-refinery.	The green or ensiled biomass is cleaned and crushed and the liquid components are separated by compression. All soluble components remain in the grass juice and the remaining solid grass fiber press cake is freed from adhesions. Grass juice and grass fiber are available as raw prod¬ucts for further processing.	A green bio-refinery is typically coupled with a biogas plant. This is because a part of one or both fractions (grass juice and grass fiber) is always utilized as a co substrate for reasons of process technology. For economic purposes, the water/heat flows from the grass processing plant and the biogas plant that are coupled to each other. The grass juice either goes directly into the biogas plant or its ingredients (for example, lactic acid, acetic acid, proteins and amino acids) are separated. Grass juice (with or without separation of ingredients) can also be used as raw material or to sup¬plement or for fermentation processes. The grass fiber can be processed directly into animal feedstuff or used as raw material for fiber-based products. Examples of fiber based products are insu¬lation materials, cellulose fibers and fiber reinforced polymers. After decomposition and hydrolytic degradation/saccharification, the grass fiber fraction can also be of interest as a raw mate¬rial for fermentation. The hydrolysate-based fermentation prod¬ucts are either chemical intermediates or are further processed into finished products. Residues from grass fiber processing are then utilized for the biogas plant as a co-substrate.

Table 1 (cont)

Biorefinery type	Platform	Raw materials	Primary Refining	Secondary Refining/Products
Synthesis gas biorefinery	In a synthesis gas bio-refinery, there is no separate component separation during primary re¬fining; instead, all organic constituents and biomass components are broken down in such a way to pro¬duce the raw product synthesis gas. The advantage is the flexibility for product manufac¬turing; products range from fuels, such as Fischer- Tropsch diesel and methanol, to higher alcohols and chemicals and even synthetics.	Numerous lignocellulosic biomasses are taken into consideration as sources of raw material: dry agricultural residues (e.g. straw, bagasse, peels and husks, corncobs), energy crops (annual and perennial grasses), wood and woody biomass, dry biogenic residues, and waste materials (e.g. paper waste, lignin). For reasons of quality and quantity-related availability, above all agricultural residues (cereal straw) and wood (forest wood, poplar short rotation wood) are of significance.	The first step in primary refining is the pre-treatment and drying of the biomass. With the strength varying according to process variant, this is followed by thermal cleavage of the biomass at high temperatures and sometimes also under pressure. The heat cleaves the long molecular chains and results in numerous liquid and gaseous hydrocarbons with shorter chain length along with increased carbon monoxide, carbon di¬oxide, carbon, hydrogen and water. The composition of the gas mixture and the characteristics of the pyrolysis products can be influenced by the process condi¬tions of temperature, pressure and time of exposure in the reactor as well as by added chemical agents and catalysts. Variations and intermediate steps are possible depending on the applied procedure. This initially produces pyrolysis slurry, which is ther¬mally gasified or is subjected to upstream torrifica¬tion. Different technologies also exist for gasifica¬tion. A necessary last step is the post-treatment and purification of the synthesis gas. Crude synthesis gas is available as raw product for further processing.	The gas composition of the crude synthesis gas depends on a range of process parameters and also determines subsequent use. At any rate, comparatively elaborate and com¬plex gas treatment along with cleaning must be adapted which is required later for subse¬quent synthesis. The following step is the synthesis step, in which carbon monoxide and hydrogen from the synthesis is further chemically processed, directly into chemical intermediates (e.g. methanol or dimethyl ether (DME), into fuels (e.g. so-called biomass-to-liquid fuel), into bio-based hydrogen, or into chemical products. Direct energetic use via a stationary motor is also possible (to generate electric¬ity and heat) as a motor fuel for mobile use. The utilization of interesting nutrients from the remaining residues for agriculture and forestry including possible treatment and recirculation will be the subject of future development of separation and purification procedures.
Biogas Biorefinery	In a biogas bio-refinery there is no separate component separation in primary refining; instead, a large proportion of the organic ingredients and components of the biomass are removed (with the notable exception of lignin) producing raw biogas.	Diverse types of biomass are suitable as a raw material base, as long as they are not highly lignified. Moist biomass above all is well suited for biogas production. This includes organic residues from agriculture (animal excre¬ment such as slurry and solid manure, crop residues such as beet leaves), organic residual materials from the food processing industry (fruit and vegetable residues, stillage, spent grains), as well as municipal biogenic waste (organic waste, food waste, green waste, landscaping green stuff) along with agricultural biomass grown specifically for energy production (so-called energy crops such as grain crop silage, corn silage, perennial grasses).	In a biogas plant, the applied sub¬strate is subjected to anaerobic microbial degradation (fermentation). A variety of types of microorganisms use the complex biomass compositions (mainly car¬bohydrates, fats and proteins) as a source of nutrients and energy. The main degradation products are methane and carbon dioxide. Because these are gase¬ous, they separate from the fermentation and form the main components of the biogas. The biogas and digestate are subsequently available as a raw product for further processing.	The gas composition of the biogas depends on a range of parameters, first and foremost the substrate composition and the mode of operation of the fermentation container. The methane content is typically around 50-70%. The energy content of biogas means that it can be used diversely for the provision of electricity and heat in cogeneration processes, for pure energy recovery (condensing boiler) or as vehicle fuel. Due to gas network requirements, the processing of the biogas into biomethane is necessary for feed-in to the existing natural gas network along with the dry¬ing and desulphurization of the gas which primarily involves the removal of carbon dioxide (CO2). The utilization of biogas can therefore take place either directly at the biogas plant e.g. via a cogeneration plant (CHP) for the production of electricity and heat or indirectly after comprehensive biogas treatment via the feeding-in to the gas grid or the use of bio-methane as fuel. While the digestate can be used materially and energetically, it is nevertheless usually deployed as a fertilizer in agriculture in order to're-close' the nutrient cycle.

4.3. Strategy and Recommendations

4.3.1. Strategy

How to achieve the goals stated in the vision taking into account the current status?

One of the key parameters to make bio-refineries a successful endeavor is bringing together key stakeholders normally operating in different market sectors (e.g., agriculture and forestry, transportation fuels, chemicals, energy, etc.) in multi-disciplinary partnerships to discuss common bio-refinery-related topics to foster necessary R&D trajectories and to accelerate the deployment of developed technologies (platform function). We can contribute to the successful emergence of bio-refineries by identifying the most promising bio-based products i.e. food, feed, value-added materials (fiber-based) and chemicals (functionalized chemicals and platform chemicals (building blocks)) to be co-produced with bioenergy, to improve overall process economics and minimize the overall environmental impact .

One of the main drivers for the establishment of bio-refineries is the need for sustainability. Impacts on international and regional dynamics, end-users and consumer needs and investment feasibility also have to be taken into consideration. Firstly, politicians, farmers and industrial stakeholders immediately need to understand impact of their actions across the value chain. When politicians understand the effect of regulatory requirements on the prices of fuel and the commercialization of renewable fuels, they can establish policies that not only benefit individual fuel sources, but also India's greater energy needs. Those farmers and other stakeholders who are skeptical about the advantages of biomass need to be convinced so that they can become active players across the value chain. Additionally, enhancing outreach and education may help spur serious discussions on innovations in both land-based and water-based biomass.

Policies like biofuel blending program and renewable purchase mandates are critical in making bio-refineries successful in India.

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With special reference to the Indian scenario:

Acknowledging India's geographical diversity would be advantageous. It has a vast coastline and in areas that are less suited to land-based biomass cultivation, it would be beneficial if innovations in water-based biomass were accepted by a wide range of stakeholders. Finally, for this industry to become established, it is important to address concerns regarding its commercial viability. A business framework needs to be created that enables bio-refineries to become competitive by setting frameworks for managing scale and enforceable targets with real incentives. Patient capital could help to commercialize the industry. This funding has worked well in the United States, as it helped socially relevant enterprises to jumpstart their progress at the beginning of their life-cycle.

A major concern for India's bio-energy will be finding a balance between capital subsidies and tariffs. It is not clear whether fiscal support for capital expenditure would be more supportive than continuous production-linked incentives, such as tariffs. It will be necessary to identify the most effective policies and regulations. Different states have different policies in place to promote biobased and renewable energy. Bio-refineries are expected to contribute to an increased competitiveness and prosperity by responding to the need to supply a wide range of bio-based products and energy in an economically, socially, and environmentally sustainable manner. Bio-refineries show promises both for industrialized and developing countries. New competencies, new job opportunities and new markets are expected to be realized while the development of bio-refineries will contribute to the realization of renewable energy, environmental and rural development goals.

With special reference to the European scenario:

European industries should develop an extensive network of regional/rural bio-refineries producing food, biofuels and numerous biobased products from local biomass in a sustainable way. This will lead to significant economic growth and created millions of jobs in rural areas. Innovative high-tech companies should be able to prosper around larger regional bio-refinery units. These companies will specialise in producing a range of high-value products from biomass fractions and side-streams coming from the main bio-refinery process, and create skilled jobs in rural areas. Decentralised, small-scale bio-refineries are also part of this development.

In Europe, integration of supply and manufacturing chains and increased collaboration between innovative players from traditional industries such as the chemical, energy, agriculture and forestry sectors will combine the key strengths of each sector, creating the critical mass to attract investors, policymakers and young talent. This will become the basis for maximising the value added to biomass streams. An open and collaborative approach creates synergies in education, research, development and innovation throughout the bio-refinery value chain. Most bio-refineries are closely integrated with traditional biomass processing industries. However, some have been established to exploit new value chains, such as aquatic/marine biomass.

4.3.2. Research recommendations

Based on recommendations made during the SAHYOG Mini-SYMPOSIUM and TWINNING WORKSHOP "Developments in Sustainable Biomass Valorisation EU-India R&D collaboration on Biomass and Biowaste, 28-29 October 2013, Utrecht, The Netherlands", as well as the ensuing Survey on EU-India Cooperation (refer to http://www.sahyog-europa-india.eu/survey-eu-india-cooperation) which was completed by a large number of stakeholders from EU and India, the following is a summary of research recommendations made for increased EU-India collaboration in the field of Bio-refineries.

Overall, research recommendations were distinguished in eight categories of Bio-refinery topics. These eight categories include:

Lignocellulosic bio-refineries towards production of fuels and chemicals extraction;

Anaerobic digestion, in combination with added value chemicals;

Demonstration of bio-refineries;

Thermochemical bio-refinery systems;

Development of new bio-refinery systems (e.g. furfural, protein or inorganics route);

Development of (smart) bio-refinery equipment based on process intensification;

Oil-based bio-refineries for production of fuels and chemicals;

Bio-refinery based on gases (CO_2/methane) towards fuels and chemicals

Based on the stakeholder survey which included responses from some 210 stakeholders both from EU and India, the three main priority areas for research for EU-India cooperation are (1) Lignocellulosic Bio-refineries, (2) Anaerobic Digestion, and (3) Demonstration of Bio-refineries. In addition, three minor priority areas for EU-India cooperation include (4) Thermochemical Bio-refinery systems, (5) Development of New Bio-refinery systems, and (6) Development of smart Bio-refinery equipment. Finally, based on the stakeholder survey, the Oil-based bio-refineries for production of fuels and chemicals and Gas-based bio-refineries would not be considered as priority areas for EU-India cooperation, although research is needed to further develop these bio-refinery types. In the following section, 5 of the 8 priority areas for EU-India collaboration in Bio-refineries are further described in detail.

Within the Lignocellulosic Bio-refineries priority area, a diversity of research and development topics are listed, which include, among others, the development and utilization of smart enzyme systems for simultaneously conversion of cellulose and lignin, development and economical assessment of more active, cheaper enzymes for hydrolysis of lignocellulose, and research and development of yeasts that can produce cellulases and convert sugars in a range of biobased products and fuels. Furthermore, development of conversion methodologies for lignin towards bioaromatics through biological, chemical and thermal catalysis is listed as important area for EU-India collaboration, in addition to Research and demonstration activities on process intensification to achieve more cost-competitive lignocellulosic bio-refineries. Finally, the development of bio-refinery systems based on fast growing and/or easily available biomass resources (bamboo, dedicated energy crops, etc.) is included in this priority area as well. For the most part, research activities in this area are in the medium to long term range and include both fundamental research as well as applied research activities.

The Anaerobic Digestion priority area equally includes a number of diverse topics for EU-India collaboration, that are generally focused on improving the overall efficiencies and reduction of costs of anaerobic digestion (reduction of retention time, increase of process stability, improved pretreatment, extraction of added value compounds, upgrade gas). Research on Anaerobic Digestion should equally involve developing strategies for multi-feedstock anaerobic digestion of various types of waste, including waste water, municipal solid waste, agricultural waste and industrial waste. Specifically for bio-refinery applications, the development of a multiple-product approach for anaerobic digestion (hydrogen, VFA, digestate) for bioenergy, biochemical and biomaterials application. Other research topics of interest for EU-India cooperation include the development of easy-to-operate and inexpensive anaerobic digesters and their application demonstration in rural areas. Finally, research on the required upgrading of biogas, including biogas storage and logistics in relation to its application (e.g. injection of biogas in the grid or use in transport, and research on the use of the main byproduct, digestate, such as fertilizer substitute or fibres is included in this priority area. For the anaerobic digestion area, research activities are in the short, medium and long term, and include both fundamental and applied research, as well as prototype development.

Within the topic of Demonstration of Bio-refineries a number of activities are included, such as setting up of demonstration-scale bio-refinery systems geared at low volume-high value/high volume-low value input/output systems. In addition, the demonstration of integrated demo bio-refinery systems that produce various energy carriers as well as food or feed products could be implemented, as well as the Demonstration of small, decentralized biomass densification programmes. Within this Demonstration area, the research activities would for the most in the short term area, and involve demonstration-type research activities as well as applied research.

Within the area of Thermochemical Bio-refinery system development, creating more efficient approaches by combining thermochemcial and biochemical conversion pathways within one bio-refinery, is a priority area. For instance, common thermochemical conversion technologies such as pyrolysis and gasification, can be combined with enzymatic hydrolysis and fermentationt, common biochemical conversion routes. Other important priority areas for collaboration are the development of a pyrolysis oil platform for producing advanced biofuels and biochemicals, and the development of a combined process based on pyrolysis and gasification for producing advanced biofuels and biochemicals. For the most part, research activities in this area are in the medium to long term range and include both fundamental research and applied research activities, as well as prototype development.

Within the area of Development of New Bio-refinery Systems, three topics of interest are listed for increased EU-India cooperation. Firstly, activities should be geared towards the development of new routes for producing biochemicals based on Furfural-based chemistry. Secondly, new routes should be developed for producing biochemicals from protein-based biomass and biowaste resources. Finally, the development of a bio-refinery systems leading to recovery of inorganics such as silica, K, Ca, other nutrients, should be further pursued. In this area, research activities are expected to be in the medium to long term, and include both fundamental and applied research.

In summary, the research recommendations described above are also presented in Table 2.

Table 2. Research Recommendations for different Bio-refinery Priority Areas

Biorefinery Priority area	Research Recommendations
Lignocellulose-based Biorefineries	
	Development of smart enzyme systems for simultaneously conversion of cellulose and lignin from lignocellulosic feedstock.
	Development, utilization and economical assessment of more active, cheaper enzymes for hydrolysis of lignocellulosic biomass.
	Research and development of yeasts that can produce cellulases and convert sugars in a range of biobased products and fuels
	Development of conversion methodologies for lignin towards bioaromatics through biological, chemical and thermal catalysis.
	Research and demonstration on process intensification to achieve more cost-competitive lignocellulosic biorefineries.
	Development of biorefinery systems based on fast growing and/or easily available biomass resources
Anaerobic digestion	
	Research and developments to improve the overall efficiencies and reduction of costs of anaerobic digestion
	Development of strategies for multi-feedstock anaerobic digestion of various types of waste, including waste water, municipal solid waste, agricultur
	Development of a multiple-product approach for anaerobic digestion (hydrogen, VFA, digestate) for bioenergy, biochemical and biomaterials applica
	Development of easy-to-operate and inexpensive anaerobic digesters and their application demonstration in rural areas.
	Research on the microbiology of AD for different feedstocks, including pre-treatment (e.g. separate hydrolysis), mixed culture systems, use of enzy
	Research on the required upgrading, storage and logistics of biogas in relation to its application, such as injection in the grid or use in transport, and
	Research on the use of digestate such as fertilizer substitute or fibres.
Demonstration	
	Set up of demo-biorefinery systems (low volume-high value/high volume-low value).
	Set up of integrated demo biorefinery systems (ethanol, sugar, power, ...).
	Demonstration of small decentralized biomass densification programmes.
Thermochemical systems	
	Creating more efficient approaches by combining thermochemcial and biochemical conversion pathways within one biorefinery, like for instance pyr
	Development of a pyrolysis oil platform for producing advanced biofuels and biochemicals.
	Development of a combined process based on pyrolysis and gasification for producing advanced biofuels and biochemicals.
New biorefinery systems	
	Development of new routes for producing biochemicals based on Furfural-based chemistry.
	Development of new routes for producing biochemicals from Protein-based resources.
	Development of a biorefinery leading to inorganics as silica, K, Ca, nutrients, …

5. Markets, Products and Policies

Summary: key facts and recommendations

In both India and Europe there is a strong and increased interest to develop the bio-based economy and bioenergy, while at the same time conflicting arguments concerning increased use of biomass are of political concern. Europe has set a target (COM 2009/29/EC) to raise its present 12% share of Renewable Energy to 20% , (biomass accounting for 50% of this share), and for the bio-based economy a doubling from the present 7% to 13% of bio based products is expected by 2020 by industry. In India a similar growth is expected. Although there are no clear guidelines specifically related to the bio-based economy in India as to date, there is an ambitious plan to achieve 55 GW power generation capacity from renewable resources by 2017.

The approach to a bio-based economy adopted in India, in particular, is somewhat different to the current international approaches and to an extent avoids the conflict with food security. It is based solely on non-food feed-stocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security (National Biofuel Policy of India). The Indian government's energy policy tries to support renewable energy by providing incentives on federal and state government level. With the main objective focussing on the supply of energy and electricity to rural areas, the focus on bio-based commodities and products is currently not the main priority.

India is rich in biodiversity as well as in biomass resources. Recognising the potential of such resources is imperative, not only for meeting energy demands, but also from monetising these resources to enhance rural livelihoods and to substitute conventional feed-stocks for bio-based industries. Thus the cascade approach and altering the current focus only on energy, may economise the overall scenario in India.

It is assumed that both in the EU and India, the demand for biomass and waste for the bio-based economy will double over the next decade. Technology development and innovation have resulted in technologies that can valorise these renewable resources from biomass and waste. The current driver for the use of biomass is the Renewable Energy Directive, where many EU countries expect that about half of the obligation will be realised with biomass. Nevertheless recent years have shown a strong interest from industry, NGO's and governments to valorise the biomass by using it for chemicals and products, rather than burning it into energy. This has been addressed in the new Horizon2020 R&D Programme that was launched in 2013. However, India is still faced with many challenges and gaps, particularly those associated with technology for each of the second generation products under different processes and techniques.

It is recommended to policy makers to provide clear guidance to the market, in order to ensure a sustainable biomass production and biomass valorisation by cascading the use of biomass. Biomass and bio-waste are renewable resources, and though available, may have geographical variation in distribution. While preserving biodiversity, a strategy is needed towards smart agriculture that will simultaneously increase the amount of food produced, as well as enhance the production of bio-based wastes as feedstock to the bio-based economy. At present there are large amounts of unused or "misused" agricultural residues and wastes documented as

available in both India and Europe, which could be better valorised and made available with improved supply chain management and logistics.

Being largely rural based, it would be ideal for India to invest liberally in developing a bio-based economy in rural areas, supplemented with other locally available energy forms as appropriate (wind, solar, and small hydro).

Europe has a strong background in bio-technology, waste management and an industry that could be the world leader in the bio-based economy and second generation applications of biomass. Biomass will become available as a local resource for local conversion, as well as an international commodity and converted into large-scale plants in harbours. Biomass will be supplemental to solar, wind and geothermal energy.

The profitability as well as acceptability of the transition towards a bio-based economy will be significantly influenced by policies affecting multiple sectors such as agriculture, research, industry and trade. Thus identifying relevant policies and quantifying their specific impacts will be crucial given the variety of policy instruments (taxes, subsidies, price support, etc.) and the way they are applied. It can be recommended to move to a completely market-driven pricing mechanism for all energy and product forms under the regulatory oversight of, preferably a single, bio-economy regulatory commission.

Immediate action is required to encourage researchers and industry to join forces to develop and implement the best know-how and technologies to achieve an optimum bio-based economy. It is strongly recommended that policy makers implement policies that stimulate both a resource- efficient society, and efficient use of biomass. Creating a pool of technically qualified human resources to serve the domestic and international clean energy markets would greatly enhance the transition from the conventional fossil-based economy to a sustainable bio-based economy.

5.1. Vision

Bio-based applications and research needs are directed towards market introduction. These markets are defined by consumer needs and policy regulations. This Chapter deals with the European and Indian policies that shape these markets in interaction with public and consumer needs.

The world is confronted with an unprecedented and unsustainable exploitation of its natural resources, significant and potentially irreversible changes to its climate, and a continued loss in bio-diversity that threaten the stability of the living systems on which it depends. In order to cope with an increasing global population, rapid depletion of many resources, increasing environmental pressures and climate change, the world needs to radically change its approach to production, consumption, processing, storage, recycling and disposal of biological resources.

A bio-based economy is part of a resource-efficient world and holds a great potential: it can maintain and create economic growth and jobs in rural, coastal and industrial areas, reduce fossil fuel dependence and improve the economic and environmental sustainability of primary production and processing industries.

In Europe[n] and India policies have been developed to steer in the direction of a sustainable circular economy and bio-based economy. However, the complex inter-dependencies that exist between challenges can lead to trade-offs, such as the controversy about competing uses of biomass. For example food versus material or energy applications, the use of scarce natural resources versus the environment. Though focus of biofuel programmes within India have been on non-edible feedstocks (like Jatropha, Pongamia seeds etc.) and on molasses produced as a by-product of sugarcane-based process of bioethanol production for its subsequent blending with gasoline or petrol, the issues on tariffs and subsidies have still not made the process sustainable and market-friendly.

Addressing such multi-dimensional issues requires a strategic and comprehensive approach involving different policies. Well-informed interaction is needed to promote consistency between policies, reduce duplication and improve the speed and spread of innovation.

The following societal challenges can be seen as the drivers for the bio-based economy:

- Ensuring Food Security (Production, Quality, Fair consumption);
- Climate change (Mitigation and adaptation);
- Resource security (Energy, scarce materials,);
- Ecosystem services (soil, water, biodiversity).

Moreover, governmental policies have to cover the whole area of agriculture, environment, waste, sustainable development, energy and innovation. Based on the inventory of the Research projects in India and Europe, a Strategic Research Advice has been formulated to realise a sustainable bio-based economy. This asks for smart low input and efficient agriculture, efficient bio-refineries, and efficient use of products, materials and energy in a low carbon and circular economy.

Not only governments are at stake, also consumers and producers can act in a responsive way and support the realisation of the sustainable economy. Fortunately there is a growing responsible world population, but more awareness and education is required to realise the implementation of the sustainable bio-economy. The next paragraphs will present the Indian and European approach and will result in further research recommendations for the Strategic Research Agenda.

[n] COM(2012) 11 STRATEGY FOR "INNOVATING FOR SUSTAINABLE GROWTH: A BIOECONOMY FOR EUROPE

5.2. Current Status

India

About 70% of India's energy generation capacity is from fossil fuels, with coal accounting for 40% of India's total energy consumption, followed by crude oil and natural gas at 24% and 6% respectively. India is largely dependent on fossil fuel imports to meet its energy demands - by 2030 India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tonnes of crude oil which amounts to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports. The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence India's coal imports for electricity generation increased by 18% in 2010. However, generation of grid-quality power from biomass continues to play an important role as fuel for sugar and textile mills, and has significant potential in breweries, fertilizer plants, the pulp and paper industry, solvent extraction units, rice mills, and petro-chemical plants. The total biomass power potential in India is estimated at 31,000 MW; of which surplus power generation through bagasse is 10,000 MW. India has an aggressive renewable energy programme. It has increased its share of renewable energy (electricity) from 2% (1628 MW) in 2002 to 11% (18,155 MW) in 2010.

India’s twelfth five-year (2012-2017) plan emphasises the projected derivatives from biomass or bio-based economy route for utilisation of agro-wastes as energy sources. There is a projection on markets bio-based systems which will come into operation in the near future with the production of biofuels (transportation sector) as the main focus. These biofuels can be mixed with gasoline, diesel or natural gas to compensate the fuel scarcity in the transportation sector, and also to meet the requirement of the existing National Bio-fuel Policy of 2009.

Europe

Electricity: In 2005, the total capacity of biomass power generation was 15.7 GW. With 3 GW, Germany had the highest capacity, followed by Sweden (2.5 GW) and Finland 2 GW. In 2011 the electricity produced from solid biomass in the EU was: 72.8 TWh. According to the Member State National Renewable Energy Action Plans (NREAPs), 2010 already saw 23.6 GW in place (real data is not yet available for 2010), whilst the ambitions for reaching the 2020 Renewables target would see 43.2 GW of capacity in place. There is significant variation in the national plans to expand biomass electricity production to reach the renewables targets. Poland, for example, intends to increase capacity six-fold between 2010 and 2020; Belgium plans to quadruple capacity; and many States intend to double or triple capacity (e.g. UK, Italy, and France).
Biofuels: biofuel consumption growth was firm in the European Union, rising to almost 14.4 million toe in 2012, i.e. a year-on-year increase of 0.4 million toe. However the previous years’ weaker growth trend is confirmed with growth at just 2.9% between 2011 and 2012.
Bio-heat: Heat consumption from solid biomass in the EU was 64.9 Mtoe in 2011.
Biogas: About 10.1 Mtoe primary biogas energy was produced in 2011 and the electricity produced in 2011 was 35.9 TWh. About 1/3 of the biogas is from landfill sites.

5.2.1. Policies

The following section will describe the key drivers and policies relating to biomass in both India and Europe. Ongoing policies in India will firstly be described, followed by current European policies and the European Bio-economy Strategy and its Action Plan. The text is supported by tables for both India and Europe showing an overview of the key drivers and polices in both India and Europe. For each driver policies and corresponding measures and targets have been mapped out for both India and Europe. The drivers include:

- Food security (Production, quality, fair consumption);
- Resource security (Energy/ scarce natural resources);
- Sustainability/ Climate change;
- Economic Benefits.

A comparative analysis of the information included in these tables will be provided to help see what is common for both India and Europe and to identify any differences.

India

The approach to bio-based energy or biofuels adopted in India is focused solely on non-food feedstocks as well as cane-based molasses, thus avoiding a possible conflict of fuel vs. food security, and this was proposed though the National Biofuel Policy of India (2008). The focus is on decreasing the import of fossil feedstock as well as refined petroleum products from transportation. One of the main objectives is the supply of energy and electricity to rural areas. The few major policy interventions in the area of bio- based energy are detailed below.

The policies on bioenergy and bio-based products play an important role in the development and transition towards a bio-based economy. The profitability of biofuel production is significantly influenced by policies affecting multiple sectors such as agriculture, research, industry and trade. Identifying relevant policies and quantifying their specific impacts is difficult given the variety of policy instruments (taxes, subsidies, price support, etc.) and the way they are applied[1].

Given the fact that the production of biofuels is intensive in the use of land, state governments become important players in defining and implementing biofuels policies that can be implemented effectively. Different states have different policies in place to promote bio-based and renewable energy and are implemented through state agencies like village level administrative units, forest departments, universities, research institutions, etc. Though, the Ministry of New and Renewable Energy (MNRE) is offering certain initiatives, its policy framework is not exhaustive and most of the measures are peripheral, thereby reducing their impact. Targets set by these groups, such as the Biofuel Blending Programme and Renewable Purchase Mandates, are critical. Yet without enforcement or consistent support, they lose some of their impact.

The focus of biofuel programmes within India have been on non-edible feedstocks (like Jatropha, Pongamia seeds etc.) and on molasses produced as a by-product of sugarcane-based process of bioethanol production for its subsequent blending with gasoline or petrol. It is important to prioritise feedstock-targeted blending mandates that will give a boost to alternative feedstocks besides molasses, and make them viable for biofuel production.

In various biofuel programme announcements of India it has been highlighted that feedstocks have to be sourced from wastelands without creating any diversion of farm lands for food crops (Chauhan, 2008) to prevent adverse implications for food security. Legal and political regimes for biofuels in India have been discursive and not linear with multitude of contrasting views from different types of institutions and actors. Various agendas have emerged from the national and state level legal and political frameworks, which have been translated into different types of actions in the biofuel sector for states of India- leading to both pro and anti-biofuel views. The second generation based biofuel production concept is quite nascent in India. Only in certain policy declarations post 2008, there has been a mention of the need to develop second generation based biofuel production systems in the long-run for India. In order to implement the production of these fuels on a large scale, certain key issues have to be resolved. The second generation biofuel products that are being considered for implementation in India are – Ethanol, Green Diesel, Lactic and Acetic Acid. India is faced with many challenges and gaps, particularly those associated with technology for each of these second generation products under different processes and techniques.

Currently, the second generation biofuel sector in India is mainly at an R&D stage where R&D is being carried out by the Ministry of Science and Technology, along with institutions like the Indian Institute of Technology, the Indian Institute of Science, as well as with some private and public companies. A major part of the R&D is also focussed on testing out the possibility of second generation biofuel production through feedstocks, like algae production, hydrocarbon production, strain improvement, utilisation of spent biomass, and the development of automated downstream processing, along with the evaluation of open and closed cultivation systems. However significant hurdles in technology development still need to be overcome before second-generation biofuels can be produced at commercial scale, even with the massive investments in R&D observed in recent years. Though it can be seen that there are ample biomass resources in the form of agro-residues to support the production of lignocellulosic biofuels, this potential is restricted to current uses of the residues as cattle fodder and application in certain industry. Much work remains to improve second-generation conversion pathways, reduce costs, and improve the performance and reliability of conversion processes[2]. Policies must be carefully crafted to avoid unwanted consequences and delayed commercialisation. Demonstration projects need to be set up for biodiesel and bioethanol production, focusing on conversion technologies through Public Private Partnership (PPP). Grants should be provided to academic institutions, research organisations, specialised centres and industry for promising R&D and demonstration projects.

India lacks mature technologies for second-generation biofuel production from lignocellulosic biomass, which is an abundant source of renewable energy that may be exploited in most parts of the country. Though biomass itself is cheap, the costs of its processing are relatively high. Technologies for biomass-to-biofuel conversion are also under various stages of development. The government should take positive steps towards promoting the use of ethanol and biodiesel as a fuel by providing tax exemptions, at least in initial stages. The responsibility of the storage, distribution and marketing of biofuels in India has been with the Oil Marketing Companies (OMCs). India’s biofuel policy exempts the biofuel sector from central taxes and duties. While biodiesel is exempt from excise duty, bioethanol enjoys a concessional excise duty of 16%. Customs and excise duty concessions are also provided on plant and machinery for the production of biodiesel and bioethanol. While these policies promote the biofuel sector, those promoting the production of feedstock need to be highlighted in order to fully realise the benefits provided on the processing front, since production and processing are interdependent. Though the policy mentions exemption of central taxes and duties on biofuels, sales tax, license fee, permit fee and import taxes still exist, hindering the growth and development of the industry. The policy provides no additional incentives for blenders and retailers of biofuel unlike in other countries.

Further, the design and implementation of environmental performance standards—including prohibition of practices as growing invasive species, removing excessive annual crop residue, providing incentive payments for avoided GHG payments, or retaining natural spaces as wildlife corridors—would bolster the sustainability of second-generation feedstocks.

The responsibility of the storage, distribution and marketing of biofuels in India has been with the Oil Marketing Companies (OMCs). India's biofuel policy exempts the biofuel sector from central taxes and duties. While biodiesel is exempt from excise duty, bioethanol enjoys a concessional excise duty of 16%. Customs and excise duty concessions are also provided on plant and machinery for the production of biodiesel and bioethanol. While these policies promote the biofuel sector, those promoting the production of feedstock need to be highlighted in order to fully realise the benefits provided on the processing front, since production and processing are interdependent.

Stronger focus by the government on carbon trading and renewable energy targets is needed. Legislation and regulations that reflect the benefits of producing bio-products from renewable resources, including nationally consistent and implemented sustainability criteria and frameworks can play an important role.

Integrated bio-refineries produce a range of products to optimise the use of the feedstock and improve process economics. There is a need to develop a market for the different bio-based products and improving properties of existing products, to increase the competitive advantage of these products versus their petroleum-based reference products. Product design should focus on the properties of bio-based products, using natural formulations to achieve desired effects. In other words, the bio-based products should not only meet the desired usability and durability standards and characteristics of their counterpart produced from reference chemicals, but also meet certain sustainability standards that would find larger penetration in the consumer market vis-à-vis non bio-based products. Market-driven research should aim at creating products that consumers want, and it is essential that bio-based products reach at least the same level of quality as their fossil based counterparts. Additionally, valuing biomass for bio-based products such as renewable chemicals and plastics could place pressure on existing uses of biomass e.g. pulp production or co-generation of energy in pulp mills.

Discussion with the stakeholders suggests that there is lack of shared understanding of the benefits of bio-based products and their potential to reduce our dependence on imported oil and polymers and reducing greenhouse gas emissions. Here the role of government through its public procurement that reflects and anticipates the development of bio-based products from renewable resources will play an important role.

Europe

Over the past decades many policies have been put in place or revised by the EU to tackle societal challenges and drive transformation of the European economy. However the complex inter-dependencies which exist between challenges can lead to trade-offs such as the controversy about competing uses of biomass. The latter arose from concerns about the potential impact on food security of the increasing demand for biological resources driven by other sectors, the use of scarce natural resources and the environment in Europe and third countries. Addressing such multi-dimensional issues requires a strategic and comprehensive approach involving different policies.

The European Bio-economy Strategy and its Action Plan strive to do this and aim to pave the way to a more innovative resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection. They will inform research and innovation agendas in bio-economy sectors and contribute to a more coherent policy environment, better interrelations between the EU and global bio-economy policies and a more engaged public dialogue. They will seek synergies and respect complementarities with other policy areas, instruments and funding sources, which share and address the same objectives, such as the Common Agricultural and Fisheries policies (CAP and CFP) and Integrated Maritime Policy (IMP), environmental, industrial, employment, energy and health policies. The Strategy builds on the Seventh Framework Programme for Research and Development (FP7) and the EU Programme for Research and Innovation. It supports more resource efficient food supply chains in line with the Road map to a Resource Efficient Europe and the Blue Growth Initiative.

See below an overview of European policy initiatives on the bio-based economy:

EU Policy Initiatives	**Year**	**Characteristics**
Horizon 2020 - EU Framework for Research and Innovation	2013	Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.
Innovating for Sustainable Growth: A Bio-economy for Europe	2012	COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS (COM(2012) 60)
Bio-based and Renewable Industries for Development and Growth in Europe (BRIDGE)	2006	Public-Private Partnership (PPP). Established in cooperation with the European Commission and the Bio-based Industries Consortium (BIC)
European Directive 2009/28/EC on the promotion of the use of renewable energy sources	2009	Directive Art 21 (2)
A Resource efficient Europe	2011	Flagship initiative of the Europe 2020 strategy supports the shift towards a resource-efficient, low-carbon economy to achieve sustainable growth.
Blue Growth Initiative – a	?	

strategy for harnessing the resources of the sea		
The European Strategy Technology Plan (SET)	2010	The SET-Plan establishes an energy technology policy for Europe. It's a strategic plan to accelerate the development and deployment of cost-effective low carbon technologies. The plan comprises measures relating to planning, implementation, resources and international cooperation in the field of energy technology.
European Climate Change Programme (ECCP)		The European Union has long been committed to international efforts to tackle climate change and felt the duty to set an example through robust policy-making at home. At European level a comprehensive package of policy measures to reduce greenhouse gas emissions has been initiated through the European Climate Change Programme (ECCP). Each of the EU Member States has also put in place its own domestic actions that build on the ECCP measures or complement them.
The European Commission has defined the Knowledge-Based Bio-Economy (KBBE)	.	The European Commission has defined the Knowledge-Based Bio-Economy (KBBE) as the process of bringing together science, industry and relevant stakeholders from Europe and the rest of the world. The conditions are, therefore, favourable towards the sustainable development and deployment of biotechnologies as an engine for the knowledge-based bio-economytransforming life science knowledge into new, sustainable, eco-efficient and competitive products. The term “Bio-Economy” encompasses all industries and economic sectors that produce, manage and otherwise exploit biological resources and related services., employment, energy supply and a new generation

Bio- waste utilisation - Waste Management

The EU food manufacturing sector and households alone waste about 90 million tonnes of food annually or 180kg per person. NB. This does not take into account losses in agriculture and fisheries (European Commission, 2012)

The European Parliament has adopted a resolution on the Bio-waste Management Green Paper. It calls on the Commission to propose national bio-waste recycling targets to limit the amount of bio-waste available for the least desirable waste management solutions such as landfilling and incineration. The resolution also states that in order for bio-waste incineration to become a viable alternative in the waste hierarchy, a crucial prerequisite is that it be coupled with energy recovery. The Parliament also urges the Commission to include in all current or additional impact studies on the matter the question of what type of economic incentives, funds or aids could be mobilised or created for the development and implantation of technologies permitting the proper management of bio-waste.

The current legislative approaches in respect to the management of bio-waste are divided into the following categories:

- Recycling and waste;
- Agriculture and Soil;
- Chemicals, Emissions and Industry;
- Climate Change.

The requested actions for the Member States are laid down in the Waste Framework Directive.

Comparison of information (contained in the tables below) for India and Europe

The majority of biomass -related policies in India are driven by poverty alleviation, food, resource and energy security. In Europe a number of drivers are pushing the European bio-economy forward, which are of equal importance and are inter-related. It has in recent years become apparent that in Europe a strategic and comprehensive approach involving different policies is necessary.

Both India and Europe still depend heavily on fossil fuels and both face the controversial challenging trade-off between the food supply on the one side, and biomass production on the other. In India a National Food Security Bill has been implemented to ensure food for all. In Europe more efficient food supply chains are being sought and changes in production and consumption patterns are being developed and promoted.

India and Europe share a similar idealistic view when it comes to sustainability – both striving towards a low-carbon economy with emphasis on “green” energy. Binding targets have been put in place in Europe under the European 20 20 20 strategy. In India measures taken to ensure a sustainable society include the NICRA and Cooking Stoves Initiative and the development of a centre of excellence in energy bio-sciences.

It is without doubt that the bio-economy sector needs to innovate and further diversify. The creation of new bio-based industries, the transformation of existing industries and new markets for bio-based products will become increasingly important for both India and Europe. The creation of new job opportunities comes in tandem with the need for improved training and education in order to meet these new demands for a highly skilled labour force, as well as an increase in public-private partnerships and demonstration plants to sustain the involvement of industry. In India sources of investment funds include the NABRD, IREDA and the SIDBI. In Europe there is the EBRD for funding demonstration projects and Horizon 2020 when it comes to funding European research projects.

Indian Bio-economy Drivers

Driver categories	Drivers	Measures	Targets/ Visions
Food security	- Competition between food supply and biomass production - Productivity need to be improve for growing population -	- The National Food Security Bill (NFSB), 2011 - Upgraded Bill was passed in parliament in August 2013	- To ensure food for all
Resource security	- Depletion of fossil fuel and price rise - Increasing fuel demand - Import dependency on fuel - Land scarcity	- A National Policy on Bio-fuels - Bio-diesel Purchase Policy - The National Hydrogen Energy Road Map plan - The National Bamboo Mission's by National Mission on Bamboo Applications (NMBA) - The National Mission on Jatropha Biodiesel - CO2 mitigation and biomass production by Tata Power, Mumbai	- 5% biofuels blending to achieved by 2012 and 10% by 2017 in transportation fuel - To ensure self-dependency in energy and power - Ensure use of waste land
Sustainability	- Improve economy (GDP) & achieve self-sustainability - Sustainable renewable feedstock - To achieve technical advancement - Loss of biodiversity	- The Energy Bioscience Programme of DBT - Developed Bioenergy Centres like DBT-ICT Centre for Energy Biosciences, Mumbai; DBT-IOC Centre for Advance Bioenergy Research, Faridabad and DBT-ICGEB Centre for Advance Bioenergy Research, New Delhi. - Minimum Purchase Price (MPP) for bio-diesel by the Oil Marketing Companies (OMCs) in 20 States and	- To develop centre of excellence in energy biosciences - Maximum utilization of resources, with emphasis on Green energy - Price check on fuel price - Converse forest and its biodiversity

		4 Union Territories. - Biofuel technologies and projects would be allowed 100% foreign equity through automatic approval route to attract Foreign Direct Investment (FDI), provided biofuel is for domestic use only, and not for export. - Forest (Conservation) Act, 1980 with Amendments Made in 1988	
Economic benefits	- Increasing energy demand - Demand on subsidy in agricultural sector - Increasing un-employment - Lack of technical education	- Bio-diesel Purchase Policy - Plantation of trees bearing non-edible oilseed under National Rural Employment Guarantee Programme (NREGP) - National Bank of Agriculture and Rural Development (NABARD) would provide re-financing towards loans to farmers for plantations. Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI) and other financing agencies as well as. - Demonstration Projects will be set up for biofuels, both for bio-diesel and bio-ethanol production, conversion and applications based on state-of-art technologies through Public Private Partnership (PPP).	- Improve rural development - Increase Job opportunities - Increase public private partnership - Set up training and demonstration plants

Climate Change	- Effect of climate on crop productivity - Increasing pollutions and GHG emission	- "National Initiative on Climate Resilient Agriculture" (NICRA) - National Biomass Cook-stoves Initiative by MNRE	- To combat effect of environment on agriculture productivity

EU- Bio-economy Drivers

Driver categories	Drivers	Measures	Targets/ Visions
Food security	- Competition between food supply and biomass production - Productivity losses due to climate change	- Developing knowledge base for a sustainable increase in primary production - Promote changes in production and consumptions patterns - Support more resource-efficient food supply chains	- No more than 6% of first generation biofuels for transportation
Resource security	- Large dependence fossil resources - Vulnerability of insecure and dwindling (fossil) supplies - Vulnerability market votility - Land scarcity	- Develop smart sustainable farming, fisheries and aquaculture - Integrate food- with non-food activities - Improving resource efficiency in the use of renewable resources - Improve knowledge base and foster innovation to achieve productivity increases - Implementation of an ecosystem-based management - Support global approach to more sustainable resource use	- 10% biofuels by 2020 for transportation - 20% improvement in energy efficiency by 2020
Sustainability	- Low carbon economy & sustainable primary production - Sustainable renewable feedstock - Loss of biodiversity	- Development of production systems with reduced GHG emissions, adapted to and mitigating the adverse impacts of climate change - Promote the substitution of carbon, energy and water intensive production processes by more	- GHG emission savings from use of biofuels must be at least 35%, 60% from 2018 - Biofuels and bio liquids are not allowed to be made from raw materials from

		resource efficient and environmentally friendly ones wherever possible	land with a high biodiversity value - Biofuels and bio liquids are not allowed to be made from raw material obtained from land with a high carbon stock
Economic benefits	- Building competitive bio-industries - Developing the European science base and stimulating high-skilled jobs (European Commission, 2011) - Potential for new value creation - Diversify revenues - Revitalize rural areas	- Bio economy sector needs to innovate and further diversity - Creation of new bio based industries, transformation of existing industries and new markets for bio-based products - New high skilled jobs and training options need to be developed to meet labour demands	- 130 000 new jobs and €45 billions of added value in bio economy sectors by 2025 -

5.2.2 Products & Users& markets

India

In India bio-based products and their market are in their nascent stage. The bio-based economy is a newly emerging term in the Indian context, which brings a new avenue of expanding employment opportunities. The term is however more synonymous with energy. The energy requirement of the growing economy of India is largely dependent on fossil-based products. Be it the rapidly growing transportation sector, or the increasing demand for electricity, the dependence on fossil fuels in fulfilling demands has not only created a major impact on the overall economy, but also to the environment in general. It is equally important for India to explore sources that can bring power in a distributed manner and on small scales so that over 60,000 villages that have no access to power can benefit from electricity. This is where biomass-based power, and especially biomass gasification-based power, will come in useful. Thus from an Indian context, it would be quite obvious to note that one of the major 'products' of the bio-based economy will be the biomass-based power or energy.

According to the 2011 Census, almost 85% of rural households were dependent on traditional biomass fuels for their cooking energy requirements. Biomass is either inefficiently burnt, creating both emissions and health hazards, or substantially causing higher consumption of firewood, or the cost of the stoves are too high. The nodal Ministry of New and Renewable energy has launched a National Biomass Cooking Stove initiative to address both problems. A research programme has also been initiated to identify the right stoves which could be used by households. The Ministry would like to enable the distribution of over 10 million stoves for households with some limited Government support by 2022, which would require additional funds and half a million community stoves to be installed in market mode. For this the Ministry has researched on natural draft and forced draft models of single part metallic and metal plate ceramic (ceramic composite/ industrial insulating materials) cook-stoves which are being manufactured in the country.

Biomass is also seen as a major utilisation in power generation and cogeneration projects. In addition a total of 288 biomass power and cogeneration projects aggregating to 2665 MW capacity have been installed in the country for feeding power to the grid consisting of 130 biomass power projects aggregating to 999.0 MW and 158 bagas cogeneration projects in sugar mills with surplus capacity aggregating to 1666.0 MW. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of implementation. Around 70 Cogeneration projects are under implementation with surplus capacity aggregating to 800 MW.

The market for renewable energy systems in rural and urban markets in India is set to grow exponentially. Of these, bioenergy is especially prominent. 90% of rural energy needs and 40% of urban energy needs are met by biomass (TERI, 2010). Despite this, bioenergy does not figure in most energy studies and is classified as 'non-commercial' energy. Bioenergy data are considered as 'inadequate and not up-to-date', since it is not transacted on the market (FAO, 2010). While India has progressed well in initiating renewable energy programmes in general, increasing the renewable energy (electricity) share from 2% (1628 MW) in 2002 to 11% (18,155

MW) in 2010, bioenergy programmes have not been on par with traditional sources of energy and at their full potential (MNRE, 2010).

Biomass is a complex class of feedstocks with significant energy potential to apply different technologies for energy recovery. Apart from the typical technologies as described in the preceding paragraph for biomass, energy through combustion, gasification and pyrolysis, the bio-chemical and bio-technological processes like anaerobic digestion, fermentation and trans-esterification are also being utilised to provide specific end- product and a mixture of by-products.

India also has a huge market for by-products of the fermentation and anaerobic digestion of biomass in India. Some of these are manufactured in India like Furfural (National Chemical Laboratory (NCL), Pune has developed a bench scale & patented one-step process for production of furfural by heterogeneous catalytic route), Lactic acid (Godavari Bio-refineries Ltd. with technology transfer from NCL Pune is producing lactic acid at part of their demonstration scale bio refinery in Karnataka). Likewise, there is a large potential in India in terms of the increase in production of biodiesel in India, multiple possibilities exist in terms of glycerol derivatives - Propylene glycol, Polyhydroxy-alkanoates (PHAs), 1,3-Propanediol, Glycerol Carbonates, Epichlorohydrin & others chemicals like Sorbitol, Xylitol, Hydroxymethylfurfural (HMF), Glutamic acid exists and research are underway. Besides this lager scope in cellulose derivatives from agro-residue and other waste biomass in place of cotton or wood cellulose.

Due to an increase in plastic waste in India, a law introduced in 2003, under which a ban was imposed on 20 micron plastic bags in Mumbai and Delhi. The States of Maharashtra, Kerala and J&K have also banned the use of plastic bags. An analysis from Frost & Sullivan shows that, Bio-plastics in India finds that the market grew at 30 percent in 2008 and will grow at a compound annual growth rate (CAGR) of 44.8 per cent between 2009 and 2015. And it is expected that the market will be a high-growth one due to current low volumes, but also due to high existing potential. Indian Glycol Ltd. is making bio-derived ethylene glycol for incorporation into PET. Likewise, most of these bio-based PAs are made from sebacic acid which is derived from castor oils. In India, an example of this is Arkema, who in April 2013 signed an agreement to acquire about 25% stake in IhseduAgrochem - a subsidiary of Jayant Agro, one of India’s leading manufacturers of castor oil and castor based derivatives.

India is known for its oldest medical treatment under Ayurveda, and has the world’s richest and diversified medicinal plants heritage. There are numerous meditational resources including trees, herbs, shrubs and grasses, from which some of the valuable medicines have been derived. These plants are in demand in market for commercial purpose. Plants collected in the wild are sold to middlemen or contractors in terms of weight and not in terms of numbers. Therefore, an estimate of the available biomass of traded plant or plant part is important. Likewise, plants like Jatropha curcas, Neem, Mahua and other wild plants are identified as the potential sources for biodiesel production in India, and few field demonstration plots have been set up in many States.

Biomass has the highest potential for small-scale business development and mass employment. Characterised by low cost technologies and freely available raw materials, it is still one of the leading sources of primary energy for most countries. With better technology transfer and adaptation to local needs, biomass is not only environmentally benign, but also an economically sound choice. Bioenergy can be expected to grow at a faster pace in the years to come.

Although, the Biomass market in India is still in its nascent stage, and has a strong potential to grow, the Ministry of New and Renewable Energy (MNRE) provides Central Financial Assistance (CFA) in the form of capital subsidy and financial incentives to the biomass energy projects in India. CFA is allotted to the projects on the basis of installed capacity, energy generation mode and its application etc. Financial support is made available selectively through a transparent and competitive procedure.

Meanwhile the Government has also established the Bio-Energy Council of India (BECI) to promote and coordinate the development of the Bio-Energy industry in India. The BECI is an amalgamation of the renewable energy sector in India comprising various forms of Bio-Energy including biomass (agri and organic waste) Bio-Pellets, Bio-Ethanol, Bio-diesel, Bio-oil, Bio-gas and Bio-power as the spectrum of business. The table below indicates the possible products that are envisaged for a transition towards bio-based economy.

Biofuels	Bioprocess	Bioproducts
• Biodiesel 1st , 2nd, 3rd generation • Cellulosic ethanol • Biobutanol • Bio-oil and Biochar • Bioethers • Bio- SPK (Aviation biofuels) • Dimethylfuran • Hydrogen	• Mechanical biological treatment • Thermal Depolymerization • Biomethanation • Trans esterification • Biomass gasification • Enzymatic and acid hydrolysis	• Biomaterials for biomedical applications • Bioplastics, biopolymers and bioresins • Biopesticides / biofertilizers • Biobased cosmetics • Biobased insulation materials • Bio based chemicals • Biobased Solvents for Biopharma applications • Biobased lubricants • Biobased sorbents • Biobased surfactants • Biobased flocculants • Biomass to renewable chemicals using thermochemical methods (for instance, biomass –> syngas –> chemicals)

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Europe

Official and coherent data is lacking for the EU bio-based economy. Several studies provide numbers, based on expert interviews and industry analysis. This section will be based on data from the Nova-Institute and Clever Consult.

The bio-based economy is made up of multiple products and applications, including several intermediate products and process chains. Graph 1 provides insight into the biomass flows in the EU-27 countries (Michael Carus, 2012)[o]. More biomass is used for their materials than for energy. These numbers are based on rough estimations since unfortunately there is no official data available for Europe:

[o] Michael Carus. (2012). *Bio-based economy in the EU-27*

A first quantitative assessment of biomass use in the EU

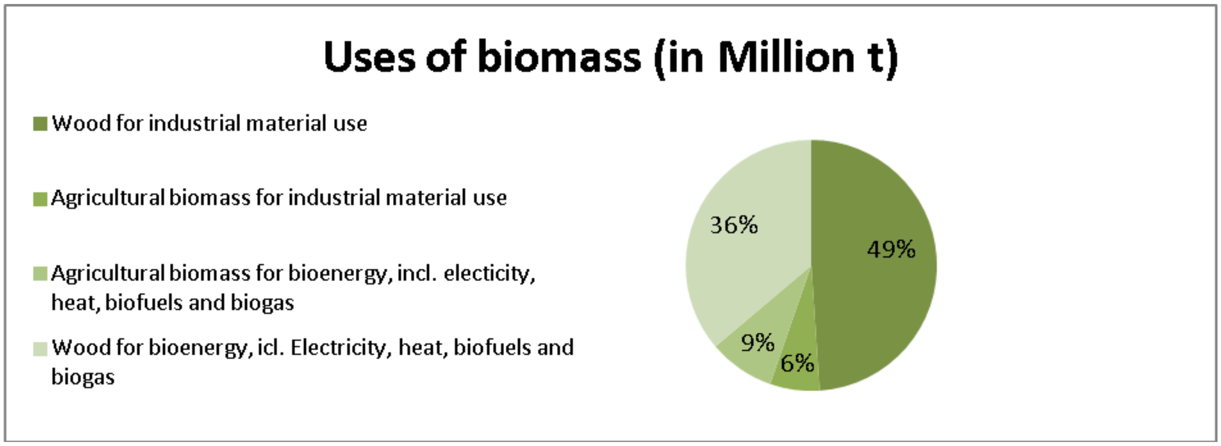
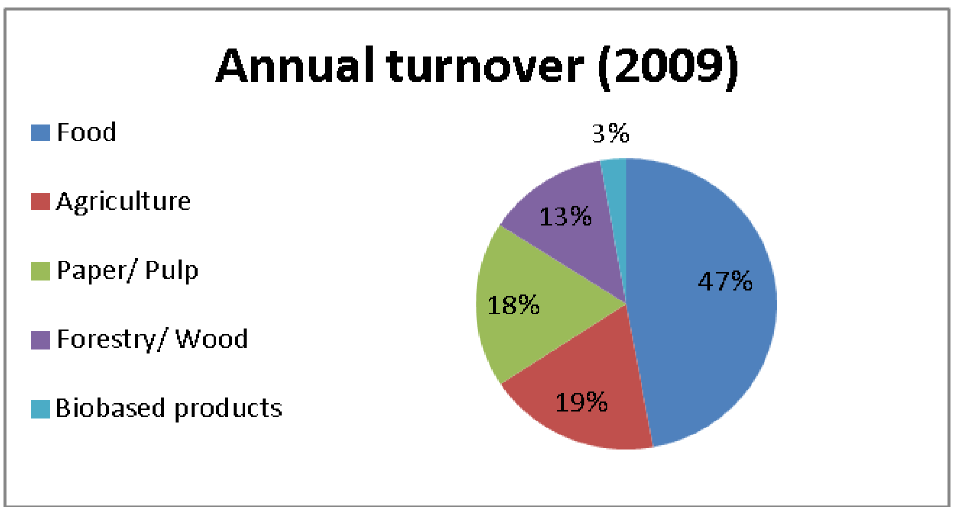


Figure 1 – Use of biomass (excl. food)

It is estimated that the European bio-economy had an approximate market size of over 2 trillion Euros in 2009, employing around 21.5 million people with promising prospects of growth (Clever Consult, 2010[p]). The bio-based sector (excl. food) in the EU-27 appears to comprise close to 480,000 enterprises and a turnover and production value of €1.2 million (Michael Carus, 2012). Almost half of the annual turnover can be attributed to bio-based products (see graph 2). In terms of employment, the Agricultural sector is the most important for the EU, followed by bio-based products (see Figure 3).

Figure 2



5.3. Strategy and Recommendations

In India the main emphasis on biomass is as a source of power, whereas in Europe the emphasis lies more on the valorisation, chemical side. Strategically, especially in India, it is recommended to carry out more research on the improvement of biomass production,

[p] Clever Consult. (2010). *The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges - Full Report.* Meise.

sustainable forestry management and, given the large availability of marine resources in India, research into aqua-bioenergy should be further exploited.

The EU needs to produce “more with less” and develop smart sustainable agricultural farming. Forestry, fisheries and aquaculture has also been identified as a key area for further research by the European Commission. Research into bio-refinery will be of increasing importance in Europe.

India’s current energy demand and the attempt to reduce import bills on fossil fuels will foresee the focus of Government policies on bio-based energy. However, the experience of the EU on prioritising a cascade approach towards a bio-based economy may provide incentives to industry to come forward, making the entire scenario more economically viable. This will also open up the potential market, currently largely untapped in India.

Research in Europe is currently somewhat fragmented. A more coherent approach and well informed interaction is required to promote consistency between policies, to reduce duplication and to improve the speed and spread of innovation. In particular more interaction and better alignment is needed between the EU and research and innovation, and the priorities of bio-economy supporting policies. It is recommended that a new Policy framework for the EU be coordinated by the European Commission, the European Parliament, Member States and regions including all sectors involved such as agriculture, forestry, enterprise, energy, environment and research. Fostering of effective governance and involvement of society for the bio-economy concept to succeed is needed, whereby public acceptance is crucial.

The European Commission’s proposal for Horizon 2020, and the Strategy and Action Plan for a Sustainable Bio-economy in Europe mention the use of public- private partnerships (PPP’s) in the form of a Joint Technology Initiative (JTI) for bio-based industries. On 10th July 2013, the European Commission launched its Innovation and Investment Package containing 5 JTIs, including the newcomer on Bio-based Industries. The PPP is an instrument to support industrial research and innovation, to overcome the innovation ‘valley of death’, the path from research to the market place. It encourages partnerships with the private sector to fund and bring together the resources needed to address the challenges involved in commercialising major society-changing new technologies. Industry is organised in a Bio-based Industries Consortium. The Consortium currently brings together more than 60 European large and small companies, clusters and organisations across technology, industry, agriculture and forestry. They have all committed to invest in collaborative research, development and demonstration of bio-based technologies within the PPP.[q]

There are clearly certain technology gaps observed in second and third generation bio-energy options in India. There have been focused interventions by various nodal Ministries to enhance the utilisation of bio-based wastes and residues as value based feedstock, but transfer of technologies and collaboration from industries between EU and India may help bridge the gaps and to move towards better and economically sustainable innovations.

[q] http://biconsortium.eu/

5.3.1. Strategy

How to achieve the goals stated in the vision taking into account the current status?

Main points for consideration from the Indian side:

- Biomass power is of strategic importance to India as India has surplus of about 623.81 MMT of biomass per year from Agriculture alone.
- Although the potential for the biomass sector in India is huge, very little of it has been tapped so far.
- Logistics like biomass harvesting, transportation and storage is the big challenge according to the current Indian scenario.
- In India the biomass-energy is obtained from biomass primarily through the techniques of direct combustion and gasification.
- Indian States should take initiatives for ethanol blending with petrol and efforts have to be made to ensure that ethanol blending is remunerative. To make biodiesel competitive, States need to provide VAT exemption on biodiesel.
- The biomass market is further likely to assume importance as India imports the bulk requirements of petro and coal.
- Apart from biomass power being an important source of energy, it can also provide job opportunities especially in the rural areas.
- The wasteland development for the energy crop plantation can be carried out by local groups with the help of farmers.
- There is the need for decentralised biofuel units and biogas plants in Indian rural areas and for providing proper education to farmers. In addition a strong policy framework is necessary for defining the vicinity of biomass exploitation with limited licenses..
- More subsidy schemes should be introduced by government to encourage the use of biomass -based products and to increase employment opportunities.
- Encouragement should be provided to the PPP mode for Biofuel, Bioenergy and Bio-base products, for better and sustainable results.
- For product development whole chain processes (up-scaling and down-scaling processes) should be encouraged to reduce the cost of the final product.
- The gap between research (universities/ Institutes) and Industry should be minimized to save time and money.

Main points for consideration from the EU side:

- At present the driving force for utilisation of biomass is the Renewable Energy Directive (COM 2009/28/EC) where the whole of Europe is obliged to achieve 20% renewable energy by 2020 from the present 14% and where biomass, on top of solar and wind is expected to contribute to half of this. However industry and governments do see the potential in the valorisation of biomass by usinga cascading and bio-refinery approach, where first the high value components of the biomass are harvested and only the left overs and residues are used for energy[r].

[r] See; http://ec.europa.eu/research/bioeconomy/

- On 13th February 2012, the European Commission adopted a strategy for "Innovating for Sustainable Growth: A Bio-economy for Europe [42 KB] ".This strategy proposes a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges that Europe and indeed the world are already facing today. The strategy is not a new piece of legislation. Rather it aims to focus Europe's common efforts in the right direction in this diverse and fast-changing part of the economy.
- A strong Bio-economy will help Europe to live within its limits. The sustainable production and exploitation of biological resources will allow the production of more from less, including from waste. The Bio-economy will also contribute to limiting the negative impacts on the environment, reduce the heavy dependency on fossil resources, mitigate climate change and move Europe towards a post-petroleum society. The importance of the Bio-economy in Europe cannot be underestimated. With an annual turnover of around two trillion Euros, and employing around 22 million people, it is already one of the biggest and most important components of the EU economy, encompassing agriculture, forestry, food and chemicals.
- The Bio-economy is therefore not a niche area – it is about growth and jobs. Estimates show that just in terms of the EU's investment in Bio-economy research and innovation, each euro to be invested under the proposed Horizon 2020 programme for research and innovation could generate ten euros of added value in different Bio-economy sectors by 2025.
- In the new EC proposal[s] for 2030 a GHG reduction target of 40% and a RE target of 28% will result in a more level playing field for materials and energy, however it will put a pressure on the already developed market for biofuels (including 2nd Gen), so a careful transition will be needed from the RED to a new 2030 framework.
- Creating a clear streamlined and transparent regulatory foundation that supports innovation is set up in the Horizon 2020 programme and will have the funding and focus to develop the technologies to realise the 40% GHG reduction.
- Global cooperation and particularly cooperation with India is crucial to join efforts and have global impact.

5.3.2. Research Recommendations

Based on the strategy defined prior to workshops with relevant stakeholders, and on a survey on the internet, the following recommendations can be made for further research:

Policy:

Research is required to underpin policies and come to efficient and effective approaches.In general it is highly recommended to formulate policies that link the waste area to resources leading to:

- Assessment of the present agricultural and biological waste categories that can be declassified (as waste) and to be used as a resource;

[s] http://ec.europa.eu/clima/policies/2030/index_en.htm

- Development and stimulation of zero waste production systems.

Sustainability:

Based on an agreement on the sustainable production and the use of biomass for the bio-economy (fuels, biochemical, materials) a number of research questions arise how this should be obtained:

- Research into sustainability limitations and opportunities of biomass production (agriculture, forestry, aquaculture) and biomass cascading use;
- Research into development of performance criteria of bio-based products, GHG reduction, Land use etc;
- Development of Improved LCA methods;
- Have agreement on GHG reduction performance of bio-based products and bioenergy.

Products and Markets:

Bio-based products and energy need a clear place in the market and stimulation. This leads to the following research questions/ recommendations:

- Research into creating a level playing field for bio-based products and energy (EU);
- Joint EU-IN study on markets; bio-based polymers, aromats, fibres and other products;
- Development of standards for bio-based products;
- Public procurement of bio-based products.

Society and Human Capital:

The following actions and research questions need to be addressed:

- Create awareness on ecology, environment, bio-based economy at primary and secondary school level;
- Capacity building of farmers both at EU and India levels. In particular providing farmers with the proper tools to evaluate investing in energy crops;
- Provide training and improve skills in agriculture and industry.

6. Conclusions

This Strategic Research Agenda for Europe and India is built on the value chain from a) Biomass production to b) conversion into bio-refineries and c) utilisation in markets. This SRA will follow that sequence.

a) Biomass Production and availability

Biomass becomes available as a renewable resource from agriculture and forestry, or is available as waste. Only first estimations of quantities could be achieved and it is recommended to carry out further research to get better and more region specific data available for the present status and expectations for the future.

Large amounts of untapped resources are available in India and Europe from agricultural, industrial and municipal residues and waste.

Land surface for forestry and agriculture in Europe and India is limited as well as constraints in water, soil quality, fertilisation, bio-diversity and pesticide. Applications require a smart approach to increase production in a sustainable way. Historically and climate given, Europe is more forestry oriented and India more small scale agriculture oriented. A number of opportunities have been identified and require further research and exploration, with a focus on specific crops as well aquatic cultures and improved practices.

Change in policy regimes is also required for optimal utilisation of currently untapped resources.

*Data refer to 13 MS (Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Lithuania, Poland, Portugal, Slovenia, Sweden, UK)

Table 1. Comparison of Numbers and areas

Estimations	India	Europe
Number of farms (millions)	138	12
Farm size (ha/farm)	1.2	14,3
Cropped land Mha	178	113
Meadows/Pastures Mha	10	60
Utilized Agricultural Land Mha	180	175
Forestry Mha	68	157
Potential for Energy crops Mha	n.a.	0.1*

Table 2. Comparison of Biomass and Wastes

Biomass and Waste resources	India	Europe
(Millions of dry tonnes)		
Agricultural residues	214	109
Industrial Waste	n.a.	290
Municipal Solid Waste	67	251
Organic degradable content	51 %	38%
Forestry fuel wood, Mton	45	21

Valorisation of these residues might yield a huge potential for the Bio-economy, increasing the value of the product and improved environmental practice.

Research Recommendations for collaboration between Europe and India on biomass production

- development of uniform databases at the State level for potential available biomass resources
- biomass production intensification with minimum and sustainable imputs of biofertilizers, biopesticides, water and selection of crops adapted to specific soil and climatic conditions
- Supply chain management (logistics, reduction of losses, storage);
- Improved waste collection, treatment, valorisation to products and energy
- Improved characterisation and administration of biomass and waste resource flows

b) Bio-refineries

Bio-refineries are the crucial technology to valorise the biomass and waste by producing a spectrum of products and energy. It brings together the different sectors: Agriculture, Forestry, Waste, Chemicals, Fuels and Energy. Bio-refineries can be categorised and have been developed in Europe and India in the paper and pulp and sugar industry, but will now be expanded to the production of integrated food, products, chemicals and energy with a variety of incoming feedstocks.

Research Recommendations for collaboration between Europe and India on bio-refineries

- development of smart enzyme systems at lower cost price;
- development of smart microorganisms for conversion of residues and waste;
- development of smart processing equipment;
- improved thermal conversion by gasification and pyrolysis for simultaneous production of chemicals and energy;
- improved anaerobic digestion by bacteria selection, pre-treatment, post treatment to fertilizer
- development of bio-based value chains (from crop to chemical and energy);
- analysis and optimisation of geographical locations for bio-based production and products.

c) Markets, Products and Policies

The analysis of the present situation and drivers in both continents leads to the conclusion that biomass is seen as a renewable resource, but its sustainability needs continuous attention. Markets exist in Europe under the Renewable Energy Directive, and new markets are foreseen in the bio-based economy for bio-based chemicals. India has a huge energy need and the utilization of biomass for energy has the first priority. Both continents acknowledge the need for valorisation and the bio-refinery approach in the future.

Priority markets exist for Energy from waste and residues, as large volumes from agriculture and municipalities are at present unused in India and Europe (mainly Eastern Europe). The societal need for waste treatment creates business opportunities.

In the long- term a strong bio-economy supports rural development and local livelihood, creates jobs and local employment and reduces Greenhouse gas emissions. Industries are interested to develop this, but need a policy environment that enables these sustainable businesses.

Research Recommendations for collaboration between Europe and India on Markets, Products and Policies

- Develop agreement on sustainable production and use of biomass;
- Develop a common political framework stimulating the bio-based economy approach (level playing field);
- Develop standards for residues and declassify them as waste;
- Develop standards for performance criteria of bio-based products;
- Develop Public Procurement of bio-based products;
- Stimulate Zero Waste communities and production system (circular economy);
- Develop awareness programmes and education on as sustainable bio-economy with proper waste management;
- Develop Training and Education for researchers and engineers in the bio-economy (Human Capital).

This strategic research agenda has been based on the work planned and conducted under the SAHYOG project, taking into account results from other related Work Packages. Information from this document will also be analysed further and referred to in the separate Strategic Road map document.

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