Bioresources
Definition, Examples, Classification

Ans. - Bioresources are nonfossil biogenic resources which can be used by humans for multiple purposes
- such as to produce food, substantial products, and/or energy carriers
- may include agriculture, forestry and biologically derived waste
- bioproducts such as antibiotics, single cell ~~product~~ protein, alcohol etc. are derived from bioresources
- bioenergy source such biodiesel, Syngas, biogas biochar are derived from bioresources
- bioresource application provides ecofriendly environment and environmental sustainability
- may be divided into two major groups such as natural bioresources and anthropogenic bioresources
- natural bioresources directly obtained from the nature like plants (biomass), animals (fats) and microbes (like algae) etc.
- bioresources originating through human activities are anthropogenic such as rice husk, bagasse, corncob, wheat straw etc.

Classification

1. Primary Bioresources
2. Secondary Bioresources
3. Tertiary Bioresources

- primary bioresources
  * generated for a specific purpose
  * it may be generated generate in forest, agriculture or aquaculture to enable the production food, substantial products, or eventually energy
  * examples are: grain, fish, potato, algae, wood, bamboo
- secondary bioresources
  * generated during processing of the primary bioresource
  * industrial processing as by-products
  * such as bagasse, molasses, corncob etc
  * They accrue genuine from virgin materials
  * they contain low amount of impurities
  * they are produced in large quantity
- tertiary bioresources:
  * They are also parts from virgin materials
  * separated along the processing chain
  * compared to the secondary bio-resources they are residue
  * occur rather in small amounts at the generation place
  * uncontrolled modification, i.e. degradation during storage
  * their characteristics are: lower value than secondary bioresources, maintenance of green areas such gardens, other green areas, special installation with vegetation

* ~~Tertiary~~ Quaternary Bioresources.
- occur after a product was used
- may be distinguished into short, mid and long term category
- ~~in st~~ after begin of products use they are generated
- in all cases of food and feed consumption by humans and animals, they are generated.
- human feces and urine, animal excrements are the example
- such bioresources are generated with short delay of food or feed are consumpted at a time scale of hours
- in mid-term delay, the quarternary bioresources are generated in days to month after consumption
- packaging materials, newsprints are the examples.
- time frame for long-term bioresources may reach from years to centuries.
- wood construction materials are the examples which last decades to centuries till they become waste wood.
- materials used for ~~fust~~ furnitures have life-time ranging from years to decades.

Opportunities and Challenges (Bioresource Technology)

Since the commencement of industrial revolution in the late 18th century and early 19th century, energy has become an indispensible factor for mankind for economic growth and maintenance of living standard. Due to the limited fossil energy resources and environmental concerns, requirement for alternative, sustainable and eco-friendly energy sources has paid great attention in recent years. Developing alternative energy is an inevitable choice for sustainable economic growth

Many of the chemical industries depend upon the raw materials obtained from the petroleum crude. In view of the exaustible nature of [illegible] is also inevitable for their sustenance.

In view of the draughts and climatic changes, there is also threats to food security. It is inevitable to go for the development of the ~~such~~ technologies which can address such problems.

Bioresource technology has the potential to solve the problems as discussed above i.e. energy, environment, raw materials ~~(sustainable)~~ and food security by applying the bioresources.

The conversion of biomass-derived synthesis gas (syngas) into biofuels by microbial catalysts has gained ~~promisable~~ considerable attention as a promising alternative for biofuel production.

Production of biodiesel from non-food renewable resources has been receiving increasing attention in recent years because of its relevance to energy, environment, food security. ~~an~~

Anaerobic digestion of lignocellulosic biomass provides an excellent opportunities to convert bioresources into renewable energy. Rumen microorganisms, in contrast to conventional m.os. are an effective inoculum for digesting lignocellulosic biomass

Anaerobic biorefinery is an emerging concept that not only generates bioenergy, but also high value biochemical/ products from the same feedstock.

Algal biomass has received much attention in recent years due to its relatively high growth rate, vast potential to reduce greenhouse gas (GHG) emissions and climate change, and their ability to store high amounts of lipids and carbohydrates. These versatile organisms can also ~~produce~~ be used to produce biofuel.

Heterocyclic nitrogeneous bases are one of the most important compounds dangerous for the environment. Bioresource technology has the potential for efficient removal of such compounds and save the environment.

Thus there is hundred of examples for opportunities and challenges associated with bioresource technology.

Global Trend in Bioresource Technology

An International Conference on Bioresource Technology for bioenergy, bioproducts and environmental sustainability was held from October 23-26, 2016 in Barcelona, Spain. Recent trend in Bioresource Technology came under discussion.

The areas of Bioresource Technology which came under discussion are: ~~Biomass pre-treatment/fractionation~~

Work carried out in the areas of Bioresources Technology

* Biomass Pre-Treatment/Fractionation
- microalgae fractionation using steam explosion, dynamic and tangential cross-flow filtration
- impact of ultrasounds and high voltage electrical discharges on physico-chemical properties of rapeseed straws, lignin and pulps
- enhancing enzymatic hydrolysis of coconut husk through Pseudomonas aeruginosa

* Thermo-chemical processing of biomass
- an experimental approach aiming the production of a gas mixture composed of hydrogen and methane from biomass steam gasification as natural gas substitute in industrial applications
- microwave-enhanced pyrolysis of macroalgae and microalgae for syngas production
- pyrolysis of agricultural biomass residues: comparative study of corn cob, wheat straw, rice straw and rice husk.

* Algal Biorefinery
- nutrient utilization and oxygen production by Chlorella vulgaris in a hybrid membrane bioreactor and algal membrane photobioreactor systems;
- bicarbonate-based cultivation of Dunaliella salina for enhancing carbon utilization efficiency;

* lignocellulosic biorefinery
- microreactor-based mixing strategy suppresses product inhibition to enhance sugar yields in enzymatic hydrolysis for cellulosic biofuels production.
* - enhanced simultaneous saccharification and fermentation of pretreated beech wood by in situ treatment with the white rot fungus in a membrane aerated biofilm reactor.
* Biomass to fuels and Chemicals
- eco-friendly assessment of farm-scaled biogas plants
- evaluation of biochar amended biosolids co-composting to improve the nutrient-rich compost
- techno economic assessment of catalytic gasification of biomass powders for methanol production
* Biological wastes treatment / valorization
- long term performance of sediment microbial fuel cells with multiple anodes
- esters production via carboxylates from anaerobic paper mill waste water treatment
- concurrent hydrogen production and phosphorus recovery in dual chamber microbial electrolysis cell
- effect of the rxn. medium on the immobilization of nutrients in hydrochars obtained using sugarcane industry residues.
- effects of loading rate and temperature on anaerobic co-digestion of food waste and waste activated sludge in a high frequency feeding system, looking in particular at stability and efficiency.
- assisting cultivation of photosynthetic microorganisms by microbial fuel cells to enhance nutrients recovery from waste water.

Bioresources Usefulness in Health Sector: An Indian Perspective

- Indian subcontinent is well known for its diversity of forest resources
- it is also known for diverse age old healthcare tradition
- every state has different culture, language and traditions
- forest resources with different varieties of plants, herbs are also available in the states.
- as per one Sanskrit shloka," No plants on Earth, which does not have Medicine properties
- as growth of human population increases more and more, natural areas and resources are being used for construction of buildings.
- with the advancement in technology, heathcare sectors have also grown rapidly.
- new generation of synthetic antibiotics are coming in the market.
- such synthetic drugs are not properly digested in human body and have their own side effects
- such drugs also create air and water pollution during the course of synthesis
- people are getting attracted towards bioresources based drugs which are ecofriendly and don't have any side effects.
- Ayurveda are Science of life, in practice in India since ancient time, people having been using bioresources based drugs
- These drugs have curative as well as preventive

(2)

* ~~Tertiary~~ Quaternary Bioresources.
- occurs after a product was used
- may be distinguished into short, mid and long term category
- ~~first~~ after begin of products use they are generated
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- packaging materials, newsprints are the examples.
- time frame for long-term bioresources may reach from years to centuries.
- wood construction materials are the examples which last decades to centuries till they become waste wood.
- materials used for ~~fuel~~ furnitures have life-time ranging from years to decades.

- They don't have any side effect and are ecofriendly too.
- Some people in India have also been using "Gomutra" as medicine.
- India has richest area of medicinal plants, so there is an urgent need to establish the traditional bio-resources value in both national and international perspectives.

Note: The usage of bioresources are best for human, but they are limited. We decide to use herbal drugs, we must grow it. The Ongoing recognition of growing medicinal plants is due to several reasons, including establishing faith in people on herbal drugs. Many NGOs have started cultivation of medicinal plants and botanical gardens.

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Preface

1st International Conference on Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability (BIORESTEC)

With growing global interest in bioenergy, biobased product and environmental sustainability, the first International Conference on Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability (BIORESTEC) was organized from October 23–26, 2016 in Sitges, Barcelona in Spain. The conference was organized in association with Elsevier's premier journal "Bioresource Technology" (BITE), with an aim to provide a shared forum for researchers, academicians, industries, and policymakers, to discuss the current state-of-the-art and the emerging trends in biotechnology, bioenergy, and biobased products. The 1st BIORESTEC conference received tremendous response from all over the globe with 754 abstracts submitted. The scientific committee consisted of 13 eminent scientists from 11 countries. The committee then screened and selected 54 abstracts for oral and 166 abtsracts for poster presentations. Besides, there were 19 invited speakers from 14 countries. Apart from the scientific presentations, a workshop on "How to write a scientific paper and get published" was also organized for early career researchers by Elsevier.

This special issue of the journal contain 29 papers (all presented at the BIORESTEC conference) after peer-review process. These papers broadly cover areas such as biomass pretreatment, algal and lignocellulose biorefinery, biological waste treatment, white biotechnology and biomass policies, LCA and techno-economics and classified as below.

Biomass pre-treatment/fractionation

Microalgae fractionation using steam explosion, dynamic and tangential cross-flow membrane filtration

Impact of ultrasounds and high voltage electrical discharges on physico-chemical properties of rapeseed straw's lignin and pulps

Enhancing enzymatic hydrolysis of coconut husk through *Pseudomonas aeruginosa* AP 029/GLVIIA rhamnolipid preparation

The effect of surfactant-assisted ultrasound-ionic liquid pretreatment on the structure and fermentable sugar production of a water hyacinth

Impact of wet aerobic pretreatments on cellulose accessibility and bacterial communities in rape straw

Thermo-chemical processing of biomass

An experimental approach aiming the production of a gas mixture composed of hydrogen and methane from biomass steam gasification as natural gas substitute in industrial applications

Microwave-enhanced pyrolysis of macroalgae and microalgae for syngas production

Pyrolysis of agricultural biomass residues: comparative study of corn cob, wheat straw, rice straw and rice husk.

Algal biorefinery

Nutrient utilization and oxygen production by *Chlorella vulgaris* in a hybrid membrane bioreactor and algal membrane photobioreactor system

Bicarbonate-based cultivation of *Dunaliella salina* for enhancing carbon utilization efficiency

Impact of different nitrogen sources on the growth of *Arthrospira* sp. PCC 8005 under batch and continuous cultivation - a biochemical, transcriptomic and proteomic profile

Anaerobic co-digestion of microalgal biomass and wheat straw with and without thermo-alkaline pretreatment

Lignocellulose biorefinery

Microreactor-based mixing strategy suppresses product inhibition to enhance sugar yields in enzymatic hydrolysis for cellulosic biofuel production

Co-liquefaction of spent coffee grounds and lignocellulosic feedstocks

Separation of saccharides from prehydrolysis liquor of lignocellulose to upgrade dissolving pulp mill into biorefinery platform

Fed-batch operation for the synthesis of lactulose with *Aspergillus oryzae* β-galactosidase

Enhanced simultaneous saccharification and fermentation of pretreated beech wood by in situ treatment with the white rot fungus *Irpex lacteus* in a membrane aerated biofilm reactor

Enhanced volatile fatty acids production during anaerobic digestion of lignocellulosic biomass via micro-oxygenation

http://dx.doi.org/10.1016/j.biortech.2017.05.051
0960-8524/

Biomass to fuels & chemicals (LCA & Technoeconomic assessment)

Eco-efficiency assessment of farm-scaled biogas plants

Evaluation of biochar amended biosolids co-composting to improve the nutrient transformation and its correlation as a function for the production of nutrient-rich compost

Techno-economic assessment of catalytic gasification of biomass powders for methanol production

Biological wastes treatment/valorization

Long-term performance of sediment microbial fuel cells with multiple anodes

Esters production via carboxylates from anaerobic paper mill wastewater treatment

Concurrent hydrogen production and phosphorus recovery in dual chamber microbial electrolysis cell

Performance evaluation of the pilot scale upflow anaerobic sludge blanket - downflow hanging sponge system for natural rubber processing wastewater treatment in south Vietnam

Effect of the reaction medium on the immobilization of nutrients in hydrochars obtained using sugarcane industry residues

Catalytic valorization of starch-rich food waste into hydroxymethylfurfural (hmf): controlling relative kinetics for high productivity

Effects of loading rate and temperature on anaerobic co-digestion of food waste and waste activated sludge in a high frequency feeding system, looking in particular at stability and efficiency

Assisting cultivation of photosynthetic microorganisms by microbial fuel cells to enhance nutrients recovery from wastewater

We would like to thank delegates for their support to the inaugural edition of the Bioresource Technology conference, "BIORESTEC". We also thank all the authors of this special issue and the reviewers for their excellent contributions. We place on record our gratitude towards Prof. Ashok Pandey, the Edior-in-Chief of Bioresource Technology who was the guiding force behind the launch of BIORESTEC conference as well as Ms. Marie Claire-Morley and Ms. Katherine Eve from Elsevier, who helped with the organization and Mr. Sankara Narayanan P., Journal Manager and entire publishing team of BITE for their cooperation in bringing out this special issue.

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Bio-Resourses & Its Utilization in Health Sector of India

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Abstract

Ayurveda are science of life, which not only have curative drug but have describe prevention of disease. This science include all natural resources for achieve its Moto, like herbal drug, marine thing, stones (jeams), bhasma of dhatus etc. In between period whole world get attracted toward modern medicine. This modern medicine get popular due to its instant result. Slowly people realized side effect of all that chemical medicine.

Nowadays people get attracted toward bio-resource because they want to stay healthy & away from side effect of medicine. The uses of bio resource are best for human. But its sources are limited. If we decide use herbal drug than we must grow it, or else it subsequently result in the loss of their existence. India has richest area of medicinal plants. Variety of bio-resources is available in that area. So there is an urgent need to establish the traditional pathy and utilize all this bio-resources.

Keywords: Bio-resources; Health sector of India; Ayurveda

Introduction

Indian subcontinent is well known for its diversity of forest & the age old healthcare tradition. Every state of India has different culture, climates & plants. As per one Sanskrit shloka, "No Plants on Earth, Which doesn't have Medicine Properties" [1]. As growth of the human population increase more and more, natural area & resources began utilized to build buildings. Such condition invites much new disease. With development in technology and industry, healthcare sector also grow rapidly, new generation of antibiotics are coming in market. But such synthetic drugs are not digested in human body & have its own side effect. To prepare this synthetic drug pollution of air and water also occur. Nowadays people get attracted toward bio-resource because they want to stay healthy & away from side effect of medicine. Ayurveda are science of life, which not only have curative drug but have describe prevention of disease. This science include all natural resources for achieve its Moto, like herbal drug, marine thning, stones, bhasma of dhatus etc [2].

The uses of bio resource are best for human. But its sources are limited. If we decide use herbal drug than we must grow it, or else it subsequently result in the loss of their existence. The ongoing growing recognition of medicine plant is due to several reasons, including establishes faith of people on herbal medicine. Many NGO starts cultivating medicinal plants & botanical garden. Importance of 'Gomutra' well known to worlds so growing pet animals which are useful for medicine is also need of time. India have richest area of medicinal plants, so there is an urgent need to establish the traditional bio-resources value in both national & international perspective realizing the ongoing development trend.

Definition of Bio-resources

Bioresources are non-fossil biogenic resources which can be used by humans for multiple purposes to produce food, substantial products, and/or energy carriers [3].

5. Types of Bio-Resources [4]

a. Primary Bio-resources.

b. Secondary Bio-resources.

c. Tertiary Bio-resources.

d. Quaternary Bio-resources

a. Primary Bio-Resources

Primary bio-resources are generated for a specific purpose. It may generate in forest, agriculture or aquaculture to enable the production of food, substantial products, or eventually energy.

Examples are Grain, fish, Potato, Wood, algae, bamboo.

b. Secondary Bio-Resources

Secondary bio-resources are generated during primary processing (in further industrial processing) as by-products or residues, it can be generated during maintenance of large green areas.

Characteristics of Secondary bio-resources are:

a) They accrue genuine from virgin materials.

b) They contain low amount of impurities

c) They are produced in large quantities.

a. As maintenance residues they are harvested on large green areas such as parks, lawns, sport places, and dikes as genuine fractions in significant amounts under controlled conditions in ample quality in terms of purity and freshness.

C. Tertiary Bio-resources

Tertiary bio-resources are also parts from virgin materials, which were separated along the processing chain. But compared to secondary bio-resources they are residues which occur rather in small amounts at the generation place and/ or are not genuine. Also uncontrolled modifications, E.g. degradation during storage, may have taken place.

Characteristics of Tertiary bio-resources are:

i. They have lower value than secondary bio-resources.

ii. In maintenance of green areas such as gardens, other green areas, and special installations with vegetation.

iii. The plant residues are not genuine and/or often partly degraded before they arrive in a utilization facility.

D. Quaternary Bio-Resources

Quaternary bio-resources occur after a product was used. They can be distinguished regarding the time frames of their generation after start of utilization into short, mid, and long-term categories. In short-term after begin of product use they are generated in all cases of food and feed consumption in the form of human feces and urine and as animal excrements. Such bio-resources are generated with short delay after food or feed consumption at a time scale of hours. With a mid-term delay the quaternary bio-resources appear in days to months after begin of utilization.

Example No.1: packaging materials are only in use for the period of transport, newsprints for one time readings. The time frame for the long-term after use group can reach from years to centuries.

Example No.2: wood construction materials, integrated in houses may last decades to centuries till they become waste wood. Materials used for furniture construction commonly have a life-time ranging from years to decades.

Need of Use of Bio-resources

With development in technology and industry, healthcare sector also grow rapidly, new generation of antibiotics are coming in market. But such synthetic drugs are not digested in human body & have its own side effect. To prepare this synthetic drug pollution of air and water also occur. Nowadays people move toward natural thing which give less side effect and which is eco-friendly also.

Utilization

Herbs are natural products and their chemical composition varies depending on several factors and therefore varying from people to people, from energetic decoctions to the use of herbal extracts following Western methodologies of mainstream medicine.

In every country traditional medicines find foundation in magical or religious beliefs, or popular experience and the World Health Organization is engaged to establish definitive guidelines for methodology of clinical research and the appraisal of effectiveness of traditional medicine. India has ancient traditional science like Ayurveda and many cultural medicine too [5]. So its need of time to utilize these natural Bio-resources in health sector.

Discussion

India have richest area of medicinal plants, so there is an urgent need to establish the traditional bio-resources value in both national & international perspective realizing the ongoing development trend.

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NATURAL RESOURCES AS A BASIS FOR SUSTAINABLE DEVELOPMENT: BIORESOURCES - RUSSIA

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Keywords: Biological resources, vegetation communities, animal kingdom, terrestrial and aquatic ecosystems, sustainable management

Contents

Summary

The state of Russian biological resources is analyzed as an important indicator of biological security and sustainable development. Quantitative and qualitative parameters of plant and animal resources are considered for forest, swamp, tundra, steppe ecosystems and water basins. Management strategies should be based on complex assessment of the most important biological resources and a well developed ecological monitoring system providing appraisal of natural and human impacts.

Russia supports a greater area of forest than any other country in the world. Extensive territories of boreal forests with unique undisturbed ecosystems have uniquely important significance for conservation of biodiversity and sustainability of the biosphere. Rational forest use should be based on improvement of forest management, long-term forecast of forest fund dynamics, improvement of forest fire protection and defense from pests and diseases.

Non-forest areas are occupied by meadow, steppe, semi-desert, desert, tundra and swamp ecosystems. At present many natural complexes are being subjected to strong anthropogenic impact. Steppe communities retained as relics of previous extensive areas in southern Russia are largely degraded. The scale of tundra degradation has increased due to development of natural resources in the Arctic. Forest and swamp complexes in Western Siberia have suffered environmental harm as a result of development of the oil and gas industry.

Russia has unique animal resources, and their conservation, reproduction and exploitation raise complex issues. Stocks of wild animals determine not only natural processes, but the very basis for survival of some ethnic groups—those historically connected with game animals. Aquatic biological resources of Russia satisfy society needs, but their use isn't full and rational sometimes. Decreases of some important fishery stocks, for example sturgeon, salmon and carp have been caused by exceeding catch norms and poaching. The biological resources of Russia are capable of fully satisfying the needs of society because of their size and diversity, providing the ecological functions can be preserved. New legislation is required as a basis for rational management of nature.

1. Introduction

The ecological security of the country and its sustainable development depends to a great extent on the levels of use and conservation of biological resources, represented by populations, species and living communities. Their intensive use in agriculture, forestry, hunting and trapping, and the medical-biological and pharmaceutical industries is increasing every year.

Biological resources as the basis for life-support and sustainable development of humankind are inexhaustible if their direct and indirect use doesn't destroy their regeneration potential and reduce biological diversity—the main depository of genetic information. So the usage of biological resources must be adequately combined with their conservation and restoration. It is important to realize that the value of biological resources is determined not just by their utility to humans. Each plant or animal biological resource is an important element of the natural environment, providing stability to the ecological functions of the biosphere, and aesthetic value to landscapes. Thus it is necessary to have a clear concept of rational nature management, combining resource and ecological components and reflecting structural changes of the modern socio-economic situation in Russia. Management strategies should be based on complex assessment of the state of the main biological resources and development of a monitoring system to provide assessment of the negative consequences of anthropogenic impact. To increase the productivity of biological resources new plant and animal species should be researched and brought into productive use. Modern highly efficient biological technologies should be developed, and biological methods of protecting crops from pests and diseases should be improved. As Russia has great resource potential, especially in the less-developed regions, the conservation of the genetic resources of wild nature and their efficient use are considered issues of global significance.

2. Biological Resources of Plant Origin

The plant resources of the Russian Federation are of great value as the key to the natural renewal resource base required for the transition of the country, and its separate regions, onto a course of ecologically sustainable development.

The vegetation of the 1700 million ha of Russia’s Land Fund is very diverse, mainly as a result of the wide climatic, geological and altitudinal variation. The primary productivity (stores of plant material and its annual production) is the most sensitive integral parameter of ecosystem state. The change of living phytomass is determined mainly by zonal distribution. The highest storage of biomass (more than 200 t ha^{-1}) is recorded in forest regions with natural predominance of climax communities, e.g. in the southern taiga, broad-leaved and coniferous/broad-leaved forests of European Russia, the Caucasus and the Southern Far East. At the same time in the northern regions with widespread water-logging and permafrost this parameter is much less, being only 1.6 to 2.0 t ha^{-1} within Arctic archipelagos. Living phytomass in arid regions of southern Russia does not exceed 8 t ha^{-1}. The natural biota of Russia as a whole is a unique resource producing 20 tons of organic matter per hectare annually on average, forest ecosystems producing the main mass. Within the territory of Russia vegetation communities produce as much as 230 tons of living biomass calculating per capita per year.

There are three main centers of floristic richness within Russia: the Northern Caucasus, Sayan-Altai mountains and Primorye (Southern Far East). The high biological diversity of mountain territories is a result of the great differentiation of habitats represented.

The status of wild flora and plant communities provides the basis for information about rare and vanishing species requiring protection. Assessments of these species have been carried out and the information presented as regional lists in the Russia’s Red Data Books, along with regional Red Data books. The RF Red Data Book contains data on about 533 floral species in need of protection. There are 440 species (80%) of angiosperms, 11 species of gymnosperms, 10 fern species, 4 clubmoss species, 22 moss species, 29 lichen species and 17 species of fungi. Species requiring protection over the entire country had priority for inclusion in the Red Data Book.

Among 400 rare species within the flora of northwest European Russia, 140 species are requiring immediate protective measures. Other plants needing protection include 500 species in the Non-Chernozem zone, 375 species in Saratov oblast, and 188 species in Krasnodar Territory (including 127 species on the Black Sea shore). In recent years some species have disappeared, for example royal fern (*Osmunda regalis*) which grew on the Black Sea Shore, and the cinquefoil (*Potentilla volgarica*) from Middle Povolzhye. Unique plant communities can be found not only in the Caucasus but also in the Caspian region, Transbaikalia, and the Pacific coast.

Within the northern part of Western and Eastern Siberia the plant species composition is less varied because of the lack of refuges for relics and endemic species of Tertiary flora. The relatively poor species diversity in boreal ecosystems is compensated by the considerable intraspecific variation in the main forest forming tree species. The relatively small number of species does not result in any decrease of natural ecosystem resistance because it is supported by diversity of forms and local adaptation. Biodiversity research and conservation measures in this region includes specific tasks such as forest seed zoning and establishing plantations of highly productive forest stands from seeds of different origin, providing form diversity.
The vegetation cover of Russia is dominated by forests. Non-forested land includes meadows, steppe, semi-desert and desert communities, plus tundra and swamp ecosystems. The plant resources of these natural biomes represent great national wealth, which are also of global significance.

2.1. Forest Vegetation

Russia has a larger area of forest than any other country in the world. It holds more than one fifth (22%) of the world's forest area and standing volume (Figure 1). Russian forests perform very important environmental and protective functions. They include 60% of the world's boreal forests. The extensive areas of virgin boreal forests with unique ecosystems undisturbed by human activity play an extremely important role in conservation of biological diversity and stability of the biosphere as a whole.

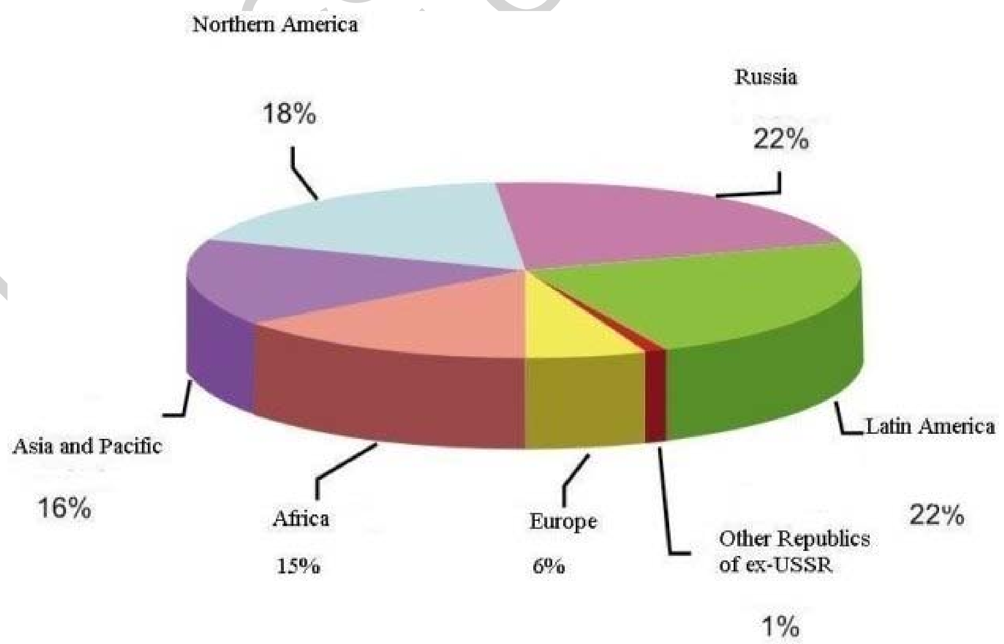

Figure 1. Distribution of forest lands over world regions.

The Forest Fund of Russia is represented by diverse forest vegetation in combination with shrub thickets, swamps and meadows. The forest vegetation can be divided into three more-or-less geographically discrete (zonal) types: 1) boreal coniferous forests accompanied by swamps and meadows; 2) mixed coniferous and broad-leaved forests with their corresponding zonal swamp and meadow types, and 3) deciduous forests to the south of the dark coniferous taiga area.

These zonal types include various classes of vegetation formations based on the dominant forest-forming tree species. Their floristic composition, structure, geographical distribution, ecological and geographical links are determined by the natural characteristics of the area: climate, geology and geomorphology, soils, hydrology, and the history of forest cover. The main types of forest vegetation within the taiga zone are the following: dark coniferous (*Abies spp., Picea spp., Pinus sibirica, P. koraiensis, P. Pumila*), light coniferous (*Pinus sylvestris*, *Larix spp*, etc.) and small-broadleaved (birch and aspen) forests. The latter type has a secondary character. These forests have appeared on the site of former coniferous forests. The main areas of dark coniferous forests are located in temperate cold and rather humid territories. These types are predominant in the western part of the taiga zone in Russia where the influence of humid Atlantic air masses is strong. Within the continental regions of Siberia extensive areas of dark coniferous forests are characteristic of mountain territories where air humidity increases as a consequence of vertical differentiation and regional climatic peculiarities. Such conditions and snow cover protection are favorable for the growth of a specific form of dark coniferous forest—thickets of dwarf Siberian pine communities which are classified as shrubs in the state forest fund inventory. They have a wide distribution in the belt below the timberline of the North-East mountain ridges.

Larch forests are widespread in regions of extremely continental climate and permafrost in Eastern Siberia and the Far East. They have local characteristics in Western Siberia and in the East Russian plain. In the southern mountains of Eastern Siberia they border the dry steppes of Central Asia, and in the northern regions they grade into forest-tundra. Pine forests are widespread over the whole forest zone, with a particularly even distribution in the western forest zone, as far as the Yenisei River. They are typical of alluvial plains, extensive areas forming on sandy river terraces. Unlike the dark coniferous forests, pine and larch forests penetrate into the steppe zone. Birch and aspen forests occur everywhere in the boreal zone. Normally they developed after coniferous forests had been affected by cutting, fires or pest invasions. In Eastern Siberia where larch forests predominate, birch and aspen forests occupy extensive areas of formerly burnt forest. Aspen is more characteristic of the southern regions, particularly on more nutrient-rich soils.

Within the territory of Russia the mixed coniferous and broad-leaved forests consist of two separate natural areas—one in the European part (the Russian plain) and the other in the Far East (Amur basin and Primorsky Territory). Woody vegetation of these regions is very diverse in composition, structure and productivity because they arose under different historical, ecological and geographical conditions. Within the Russian plain the dark coniferous forests are represented by a combination of coniferous and broad-leaved stands or by proper mixed forests. Large areas were occupied by these forests in the past but now they are mostly under agricultural and other usage.

Coniferous and broad-leaved forests of the Far East are influenced by the Pacific monsoon, which provides high air humidity. These are mountain forests mainly with a small number of tree species and dominated by Korean Pine (*Pinus koraiensis*), and various fir and spruce species. At present these forests are being subjected to intensive anthropogenic impact, which is changing their appearance, particularly by cutting and forest fires.

The deciduous forests in the southern part of the forest zone are represented by diverse broad-leaved forests with oak predominating within the Russian plain, and birch and aspen forests in the Western Siberian lowland. To the east of the Yenisei this belt is not clearly marked—there are forest-steppe small birch forests with meadow steppes in Central Siberia, and isolated broad-leaved forests with dominant Mongolian Oak (*Quercus mongolica*) in the southern part of the Far East.
Russian forests exert considerable influence on all natural processes in the biosphere. The most important ecological function is considered to be their regulation role in atmospheric composition, due to CO_2 binding during photosynthesis and carbon accumulation in wood, soils, and peat. These processes are of special importance in assessment of possible climate changes and balance of greenhouse gases in the forest ecosystems.

On a global scale Russian forests play an important role in accumulation of organic carbon (see Table 1). Most of the accumulated carbon consists of detrital remnants and their decomposition products. The store of soil carbon accumulated in Forest Fund lands is 172.4 Gt, while the carbon pool in phytomass is 34.3 Gt and its rate of deposition is 240 Mt per year. The average carbon stock in forest phytomass is 30.9 t ha^{-1} and the average deposition value 0.22 t ha^{-1}. For land entirely covered with forest these values are 44.5 t ha^{-1} and 0.32 t ha^{-1} per year. The main process providing high carbon sequestration capacity in boreal forests is ‘swamping’, or accumulation of peaty material under waterlogged conditions. The carbon store in peat and boggy soils is 114-118 Gt.

	Carbon store, Gt C	
	Phytomass	**Soils**
Russia’s forests	34.4	172.4
World’s boreal forests	57	338
World’s forests	536	704
World’s terrestrial ecosystems (excluding agricultural lands)	654	1567

Sources: Isaev A.S., Korovin G.N. Carbon in Northern Eurasia Forests // Carbon cycle on the territory of Russia. – Moscow: Ministry of Science and Technology of the Russian Federation, 1999, - p. 165-201 (in Russian); Prentice I.C., Farquhar G.D., Fasham M.J.R., Goulden M.L., Heimann M., Jaramillo V.J., Kheshgi H.S., Le Quere C., Scholes R.J., Wallace D.W.R. The carbon cycle and atmospheric carbon dioxide // Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. – Houghton J.T., Ding Y., Griggs D.J., Noguer M., van der Linden P.J., Dai X., Maskell K., Johnson C.A. (Eds.) – Cambridge: Cambridge University Press, 2001. – p. 85-98.

Table 1. The carbon pool in terrestrial ecosystems

The resource and ecological potential of forests directly depends on their qualitative and quantitative characteristics and their distribution within the country. There are about 300 tree species and a great number of shrubs and lianas in Russian forests. However the main forest forming trees number not more then twenty species. Coniferous and hard-leaved forests are the most valuable and unique due to the tree species composition ("hard-leaved forests" is a term fixed in the Instruction on Forest Fund State Account for a determined list of broad-leaved tree species, the wood of which is harder than that of soft-leaved species). These forests form the most long-lasting and resistant ecosystems, providing a regulatory influence over natural processes including carbon sequestration.

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Biographical Sketches

Isaev Alexander Sergeevich is a Doctor of Biological Sciences, professor, and academician of the Russian Academy of Sciences. He is a specialist in the field of forest ecology, forest protection from pests and diseases, forest monitoring, resource and economic policy. He is the author of more than 250 scientific works (including 6 monographs) devoted to different problems of forestry. The fundamental researches for dynamics of forest pest number based on the phenomena theory for resistance of mobile ecological systems was completed under his leadership. An applied aspect of this theory is development of models for dynamics of forest insect populations, giving possibilities of prediction and regulation of pest numbers. He is one of the founders and leading executors of the program for satellite monitoring of Russian forests. The results of this works are widely used in forestry practice for assessment of Forest Funds and impact of various natural and anthropogenic factors on forest ecosystems.

For achievements connected with protection and rational use of forests he was awarded the Prize and Gold Medal of International Union of Forest Research Organizations (IUFRO), an Honorary Diploma of United Nations Environment Program (UNEP) (Global 500), and the Gold medal of RAS after academician V.N. Sukachev. He is a foreign member of the Bulgarian Academy of Sciences and an Honorary member of the American Society of Foresters.

- 1949-1954: Student of Leningrad Academy of Forestry;
- 1954-1960: Engineer of Moscow Forest Inventory Expedition;
- 1960-1988: Scientific researcher, Leader of Laboratory, Deputy Director, Director of the Institute for Forest and Wood, Siberian Division of Academy of Sciences of USSR;
- 1977-1988: Chairman of Krasnoyarsk Scientific Centre, SD AS USSR
- 1988-1991: Chairman of the State Committee on the Forest of USSR;
- 1991-1993: Chairman of Higher Ecological Council at Russian Supreme Soviet;
- Since 1978: Chairman of Scientific Council on the Forest, RAS;
- Since 1978: Editor-in-chief of magazine “Lesovedenye”.

Rybalsky Nikolay Grigorjevich is a Doctor of Biological Sciences, professor, and academician of Russian Ecological Academy. He is a specialist in the biology of soils, biotechnology, science of theory and practice of patenting and protection of copyright, and ecological safety.

He is the author of more than 130 scientific works devoted to different problems of ecology and nature management. He was leader or participant in the development and realization of state scientific technical programs: “Ecology of Russia” (1991-1992), “Conversion to Ecology” (1991-1993), and “Ecological Safety of Russia” (1993-1995). He is the leader of the “Biological Diversity” Section within the framework of State Scientific Technical Program.

- 1970-1975: student of Moscow State University after M.V. Lomonosov.
- 1975-1980: post-graduated education in Moscow State University.
- 1981-1990: senior researcher, leader of Sector for biotechnology and ecology, All-Union Scientific Research Institute of State Patent Expertise, State Committee for Inventions.
- 1991: head of Major Department of Nature, Ministry of Nature USSR
- 1992-1994: Deputy Minister of Ecology of Russia
- 1994-1997: General Director of Russian Ecological Federal Information Service, Ministry of Nature of Russia
- Since 1997: Director of National Information Agency «Natural Resources», Ministry of Nature Resources, RF.
- Director of National Selected Center INFOTERRA UNEP
- Deputy editor-in-chief of magazine «Use and Conservation of Natural Resources of Russia»
- Member of editorial board «Regional Ecology» magazine
- Editor-in-chief of newspaper “Natural Resources Gazette”.

Lecture 1

Bioresources

Trevor Hodkinson, School of Natural Sciences (Plant Sciences)

Lecture content

-Bioprospecting and medicinal products
-Genetic resources
-Plant and animal biotechnology
-Genetically modified organisms
-Agriculture
-Water technology/waste treatment

-Bioresources in ecosystems (ecosystem services)
- carbon cycles
- pollinators and dispersal agents

Practical classes

- Carbohydrates 1 -Seed germination, starch and alpha-amylase

- Carbohydrates 2 -Pumpkins-sugars

- Cereals/domestication of plants

- Water biotechnology/waste treatment

Bioresources

- What are bioresources?

Any resource of biological origin

Restrict here to products from living organisms

Exclude e.g. fossil fuels, rocks of biological origin

Conservation and utilization of biodiversity

- Biodiversity (genetic diversity)

↓

- Bioprospect and conserve (*in situ* and *ex situ*)

↓

- Utilize (harvesting, breeding, biotechnology)

Why is biodiversity valuable?

- Value to humans
- Renewable (populations can replenish themselves)
- Indirectly contributes to ecosystem stability

Value of bioresources

- Direct value
  - Agriculture
  - Medicine
  - Bioproducts

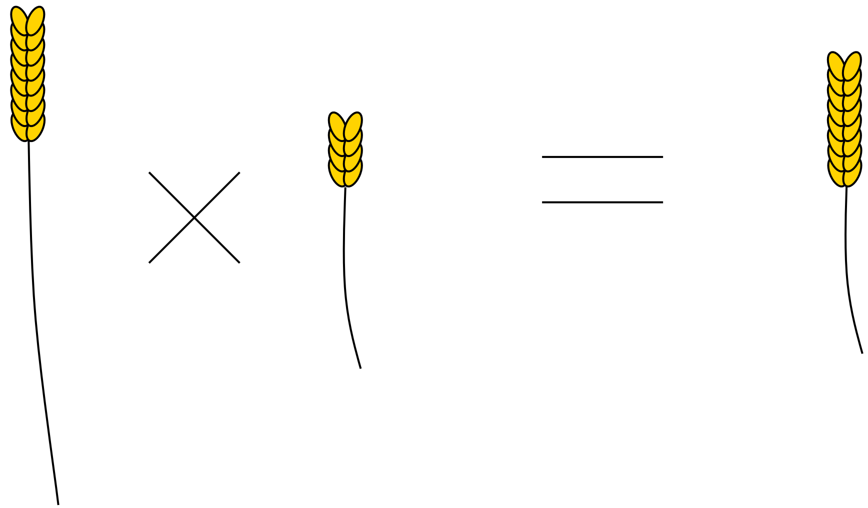
- Indirect value
  - Ecosystem services (nutrient cycling, pollination, dispersal)

Direct value of biodiversity

- Food and drink
- Medicine
- Building materials/construction
- Clothing etc.
- Energy
- Horticulture

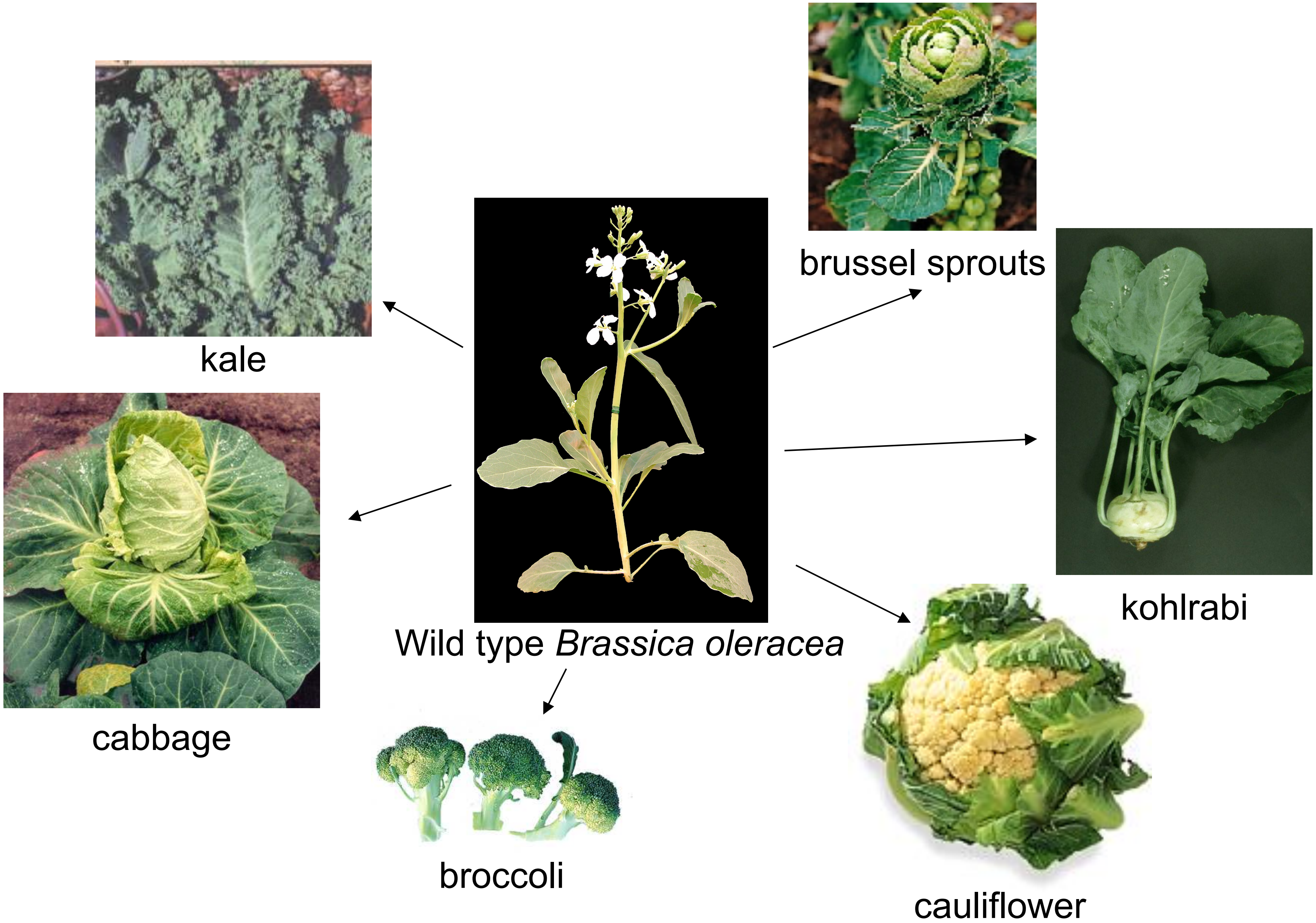
Agriculture

- Domestication and breeding programs



Eg. *Triticum* (wheat) x *Secale* (rye) → *Triticale* (via traditional crossing of plants)

Artificial selection



Plant genetic resources

- 350,000 spp. of angiosperm on earth
- 80,000 possess food value
- 3,000 used

Maize, wheat and rice
=2/3 of worlds grain crop

Within crops also little diversity –eg. Few varieties used in wheat belt of N. America, potatoes in N. America and coffee plantations in Brazil

Wild/landraces of crops

- Important as sources of genes for crop improvement
  - Increased production
  - Disease resistance
  - Drought tolerance
  - Improved nutrient content eg Golden rice (vit A, beta caroteine precursor)

    Lysine in cereals

    Sulphur cotaining aa's in legumes.

Wild relatives of crops

- eg *Zea mexicana* (Mexican teosinte)
- eg *Zizania texana* (Texas wild rice)

Importance of genetic diversity in agricultural systems

← Monoculture: efficient, high yielding

→ Intercropping: tolerant to pests, diseases, environmental change

Pests and disease

- 1840s Irish potato blight
- 1860s Vine disease, Europe
- 1870-90 Coffee rust, Ceylon
- 1942 Rice crop destroyed, Bengal
- 1946 US oat crop devastated by fungus
- 1950s US wheat stem rust
- 1970s US maize fungus

Diversity therefore important for 1)crop improvement 2) coping with changing environment

Bioenergy

- Biofuels
- Biomass (stored energy-
eg in carbohydrate)

- Maize/ *Saccharum*
- *Miscanthus*
- *Salix*

Ethanol
factory -Brazil

Animal genetic resources

- Meat (from a limited nu. of species/breeds)

Wild progenitor of cattle is extinct –breeds endangered

- Animal products (eg milk)
- Hunting
- Graft
  - Horse, donkey, camel, llama, elephant, yak…
- Manure
  - Guano – fertilizer
  - Cooking fires

Livestock genetic resources

FAO State of World's Animal Genetic Resources (www. FAO.org)

World's livestock production is increasingly based on a limited number of cattle breeds (diversity in these also in decline).

A global total of 7,616 breeds has been documented

20% of breeds are classified as at risk

One breed per month lost in the last six years

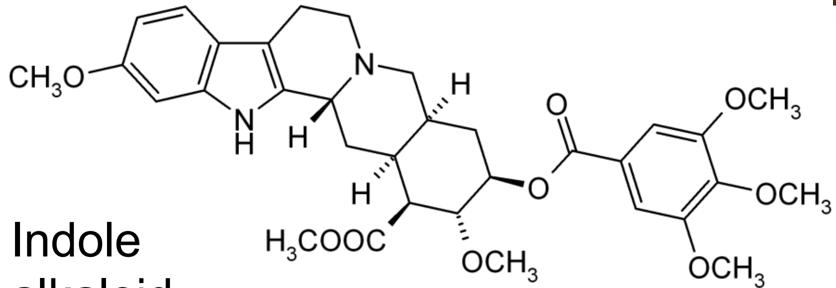
Animal genetic resources eg ***Tilapia***

- East Africa
- 164 spp in Lake Malawi
- Converts food to flesh faster than most fish
- Used in **aquaculture**

Medicinal resources

- 50% medicinal compounds obtained from plants
- Often difficult or expensive to artificially synthesise
- eg *Rauvolfia* sp. (serpent wood). India 4000yrs – nervous disorders/ mental illness

Reserpine (tranquilizer)



Indole alkaloid

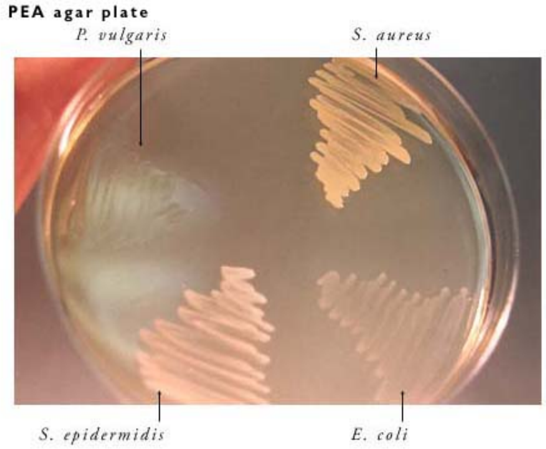
Commercial synthesis

- Natural compounds often act as “blue print”

  eg morphine and codine
- Alkaloids from opium poppies
- Used to develop synthetic painkillers
- Advantages of commercial synthesis:
  - Many plants difficult to cultivate
  - Natural compounds may have side effects

Other medicinal resources

- Agar (red algae)
- Drug testing and research



Horseshoe crabs used instead of rabbits to test endotoxins. Also –blood cells can be cultured and used instead

Rhesus monkey

Other biological resources of direct value

- Oils and waxes
- Skin/hide/furs
- Trees
  - Timber
  - Natural rubber
  - Ornamental
  - Pest resistant
  - Soil conservation/preservation
  - Wind breaks/shade
  - Nitrogen-fixing
  - Fruit

Biotechnology for new plant and animal products

- Genomics, transcriptomics, proteomics
- Tissue culture
- Genetic engineering

Potato breeding programme

teagasc

Agriculture and Food Development Authority

Just completed the first draft genome sequence (Irish part of the international consortium)

Molecular farming

- Use plants to make specific compounds/ chemicals
- Plants make carbohydrates and enzymes

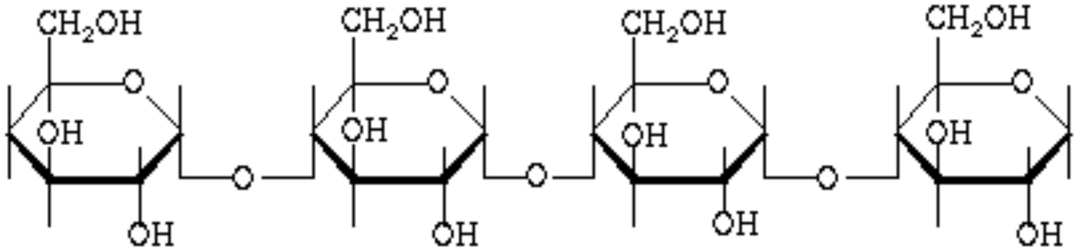
Two of most abundant carbohydrates:

-Cellulose $(C_6H_{10}O_5)_n$ –chains of dextrose (D-glucose)

-Starch (most starch not directly eaten)-polymers of glucose

Amylose

Starch -polymers of glucose

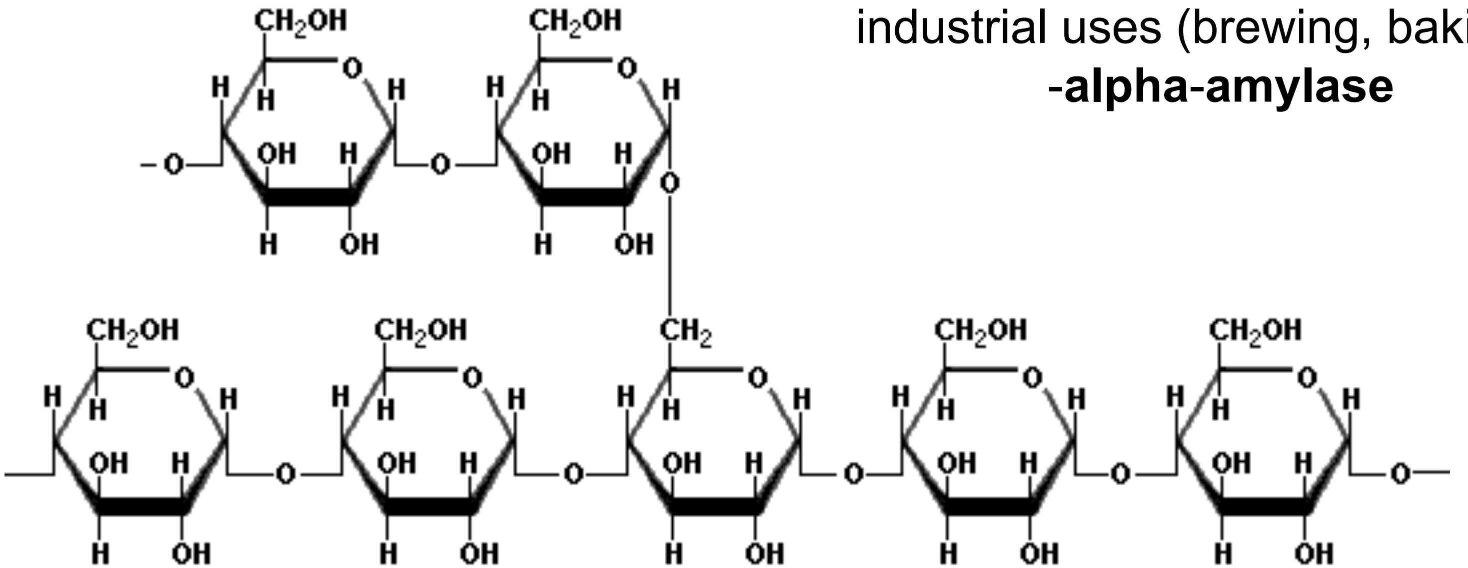


Starch broken down by alpha-amylase in grains (Practical 3)

Amylopectin

Enzymes used to process food and for industrial uses (brewing, baking, detergents)

-**alpha-amylase**

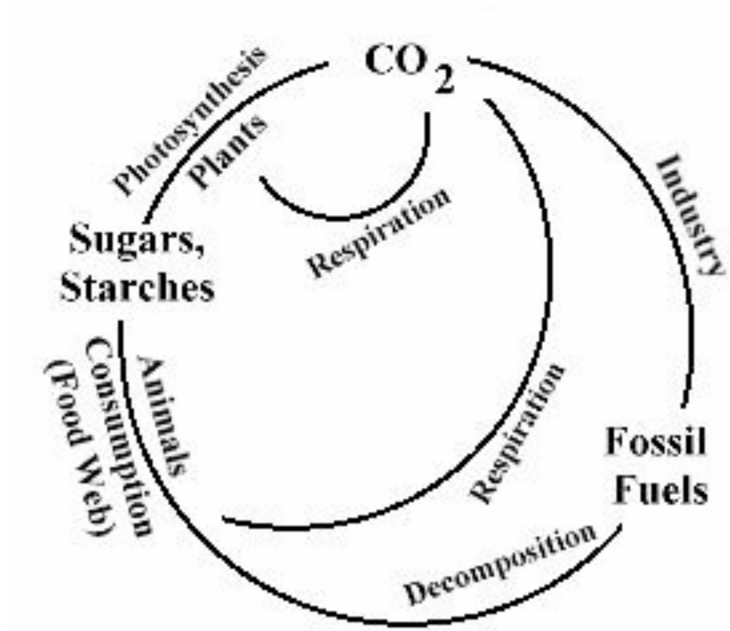


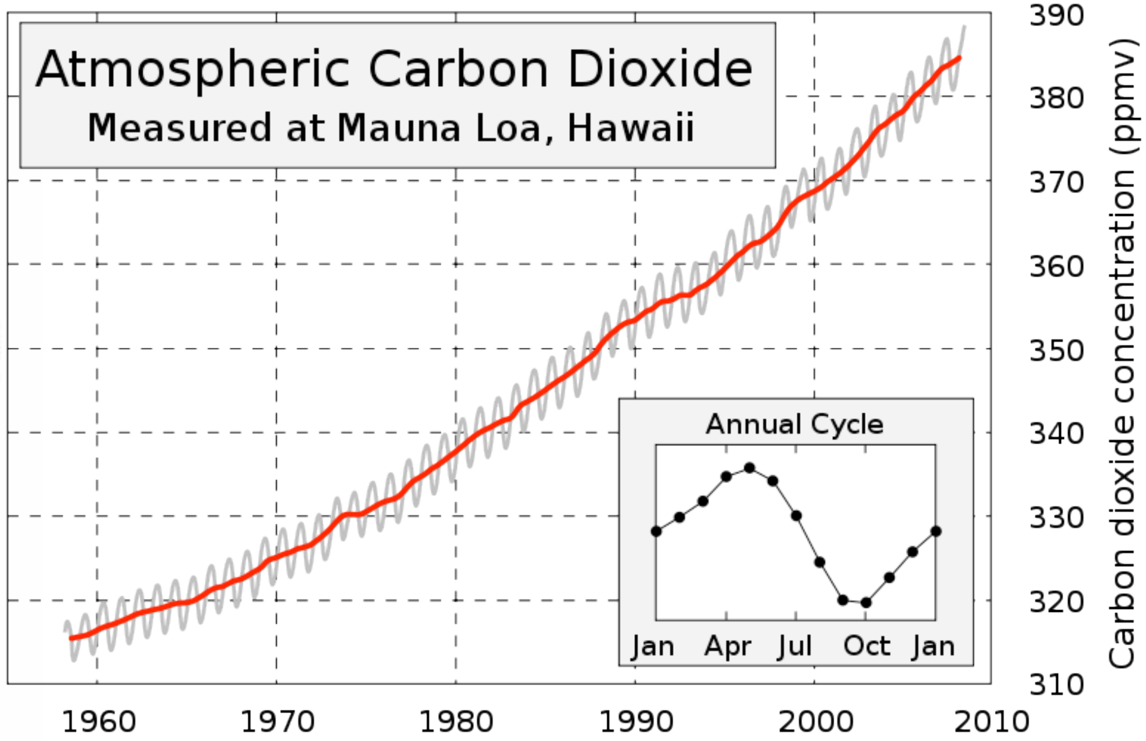
Indirect value

- Ecosystem services
  - Nutrient, water cycling, and climate
  - Soil formation and fertility
  - Detoxification of noxious chemicals
  - Indirect agricultural value

Carbon cycles

- Regulate carbon cycles
- c.387ppm atmospheric CO_2 regulated by plants





Indirect agricultural value

- **Pollinators**
  - Most flowering plants require animal pollinators
  - E.g. bees, especially native species
  - Allow us to grow crops which require cross-pollination eg apples, tomatoes
  - Service is worth $billions

Indirect agricultural value

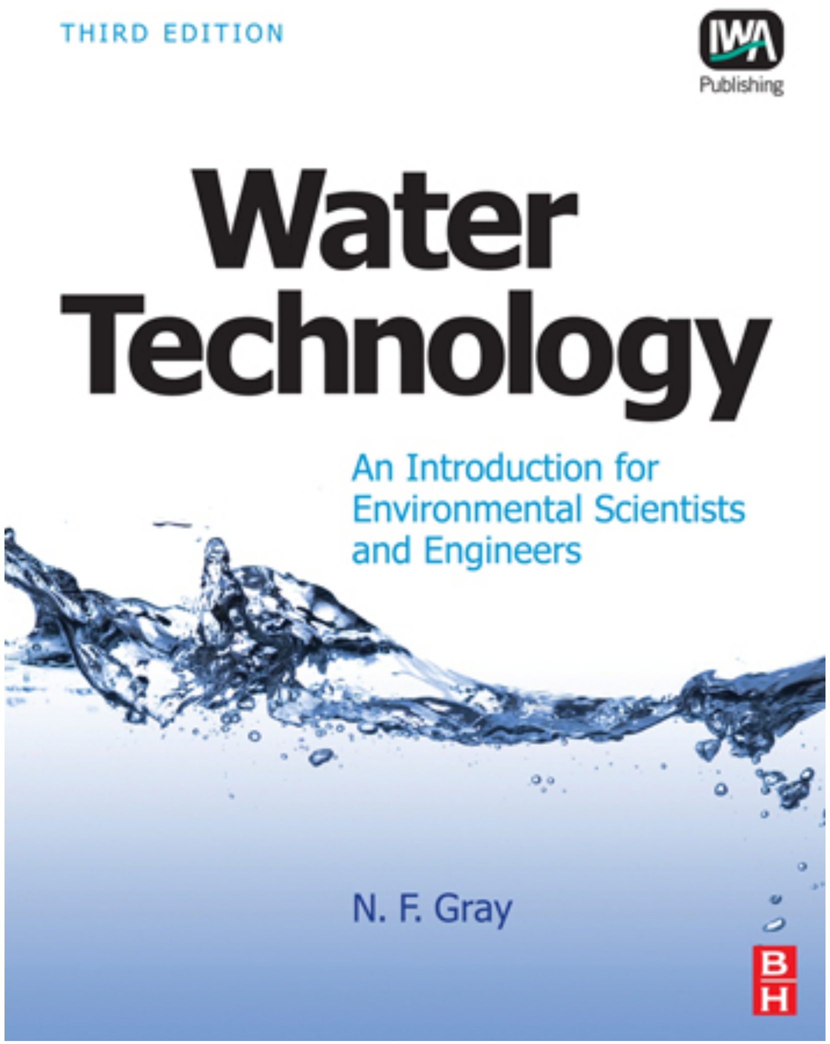
Biocontrol

Natural pest control (avoid pesticide use)

Introducing or augmenting populations of natural enemies of crop pests

- Ladybirds and hoverflies for aphid control

Water technology and waste management



Plants and microbes used to clean up water.

More from Nick Gray on this later in the module.

Value of biodiversity

- Environmental economists value global insect ecosystem services at 16-54 trillion US dollars Per Year
- Minimum estimate
- Calculated as amount it would cost to provide services by other means (if possible at all)

Pullin 2002, Costanza *et al.*, "The Value of the World's Ecosystem Services and Natural Capital," *Nature* Vol. 387 (1997).

Biodiversity benefits human welfare

- Interest in nature
- Eco-tourism
- Human desire for natural habitats

Summary

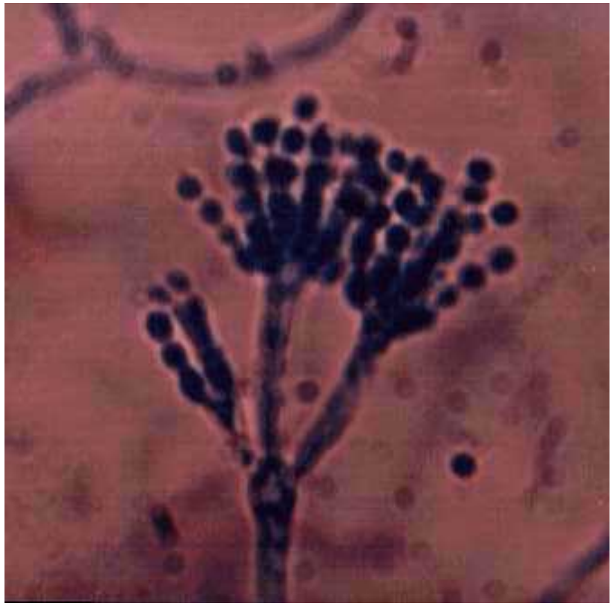
- Direct value
  - Improve current resources
  - Discovery of new resources
- Indirect value
  - Ecosystem services

Further reading…

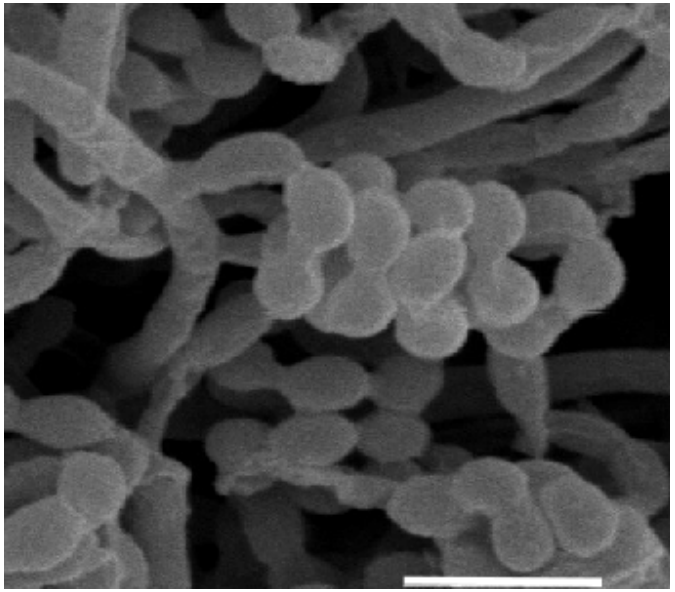
- Wilson (2002) The future of life. Chapter 5
- Oldfield (1989) Genetic Resources. Sinauer
- Pullin (2002) Conservation Biology. Cambridge University Press. Chapter 1
- Altieri (1999) The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment 74: 19-31

Old slides –not used……

Medical compounds from micro-organisms

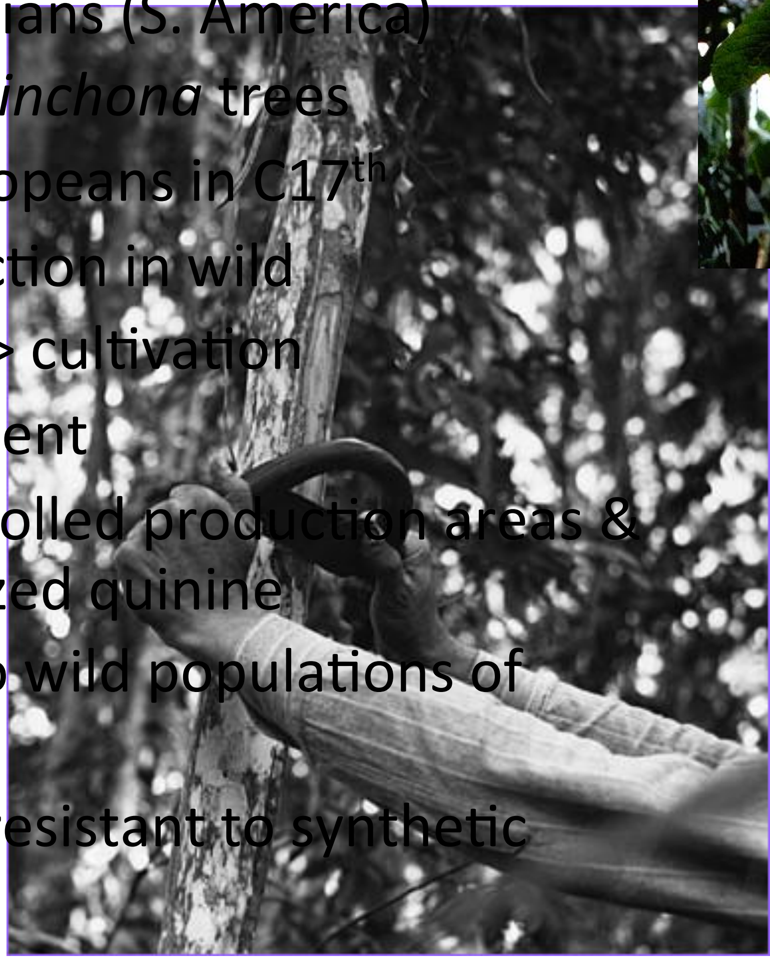


- Fungi eg *Penicillium*



- Bacteria eg *Streptomyces*

eg Quinine



- Used by native Indians (S. America)
- Bark of tropical *Chinchona* trees
- Discovered by Europeans in C17th
- Commercial extraction in wild
- Seed collections => cultivation
- Genetic improvement
- WWII: Japan controlled production areas & Germans synthesized quinine
- Allies went back to wild populations of *Chinchona*
- Vietnam: malaria resistant to synthetic quinine

eg anticancer drugs

- Madagascan periwinkle
- *Catharanthus roseus*
- drugs effective against cancer (leukaemia testicular, breast, cervical), Hodgkins disease, tumors & melanomas

Innovation Challenge towards Rational Use of Bio-Resources in Europe

A discourse book

May 2014
European Sustainable Energy Innovation Alliance
Working Group 1

Table of Content

Executive Summary

Bio-resources are on the one hand of central importance for the development of a sustainable bio-economy and on the other hand arguably among the most contested resources. Their provision, conversion and use have significant impact on the environment as well as on social and economic development. Their rational and sustainable utilisation will decide about the competitiveness of Europe in future.

The competition for bio-resources is fierce between the food and feed sector, traditional bio-resource based industries like pulp & paper and an increasingly active energy sector. Bio-resources are diverse in terms of their origin, their properties and their potential use. Primary bio-resources (crops, wood, etc.) face the fiercest competition as they have good logistic properties and a high versatility of utilisation pathways. Secondary bio-resources (agricultural and forestry residues, grass, etc.) currently face less competition and, together with tertiary bio-resources (bio-waste from industry and society), provide the highest potential for more intensive utilisation.

Bio-resources provide a large variety of services to society; their generation is a major factor in societies impact on eco-system functions. Some services, such as providing food and feed but also providing income to rural regions and providing raw materials for conventional bio-based sectors, cannot be met by other resources. For the provision of other services, bio-resources are in competition with other (renewable) resources. Any rational utilisation of bio-resources has to keep within the requirements of preserving the environment and give priority to services that may not be met by other resources.

As bio-resources are inherently de-central, European regions will play a major role in the transition to a sustainable bio-economy. The utilisation of these indigenous resources on the regional level however requires further knowledge about contextualisation of technologies and environmental, social and economic impact of bio-resource generation, conversion along the value chain, use in society and re-integration of residues. It must be based on a broad consultation process with regional stakeholders, defining both the environmental, social and economic framework and the responsibility of the region regarding the provision of services from bio-resources. Based on the results of the consultations regional bio-resource utilisation plans must be established. These plans shall integrate the modernisation of existing bio-resource utilisation sectors to become versatile bio-refineries, the establishment of longer value chains based on bio-resources, closing material cycles with least transport effort and preserving eco-system functions and using intersections of energy distribution grids for bio-refineries based on secondary and tertiary bio-resources in order to contribute to stabilising grids in a future sustainable European energy system.

eseia initiates with this discourse book a broad discussion between experts, interest groups and decision makers on the European as well as national and regional level. Starting with the pilot project “Bio-resources – the Green Heart of Styria” in 2013 it invites European regions to bring this discussion to the European citizens.

1 About the discourse book

Bio-resources will become key resources for Europe in the 21st century. Fossil resources will approach or over-run their respective maximum production rate within this century, requiring a re-orientation of European industry. Bio-resources will play a particularly important role in the transformation as they may provide energy carriers as well as raw materials for material products, besides their crucial role to feed our society. Their versatility combined with their limited availability due to the finite amount of land and sea on which their growth depends will however make them to strongly contested resources.

Fair and sustainable utilisation of bio-resources is a precondition for success of an innovative bio-economy in Europe. The Working Group (WG) *Bio-Resources* within the European Sustainable Energy Innovation Alliance (eseia) wants to contribute to the necessary discourse about their rational use. Based on the decision of the Working Group Meeting in Brussels on March 22nd, 2013 the current *discourse book* shall represent the starting point of this endeavour.

This discourse book is the result of collaboration between experts from the Bio-Resource Working Group. Key input to this text was supplied by Andreas Pfennig (TU Graz), Devrim Yazan (University of Twente), Ina Körner (TU Hamburg), Jan Harmsen (Harmsen Consulting), Yoram Krozer (University of Twente), Liam Murphy (Dublin Institute of Technology), Rupert Baumgartner (University of Graz) and the eseia Director Brigitte Hasewend. Marten Arentsen (University of Twente) and Michael Narodoslawsky (TU Graz) were in charge of editing this text.

This discourse book is not intended to be a comprehensive “end-result”. Quite to the contrary, its purpose is to ignite discourse within the expert pool of the Working Group Bio-Resources of eseia. It is an internal document of this Working Group and not designed to be distributed to a larger audience. The discourse book deliberately takes a broad look at a wide variety of aspects linked to the use of bio-resources. This strategy shall help to find points of entry to the discourse from the vantage point of different disciplines and sectors. By spreading wide the text necessarily cannot dig deep into many issues. This of course does not mean that the importance of such issues is disregarded by the authors of the discourse book. Wherever experts find issues that are treated superficially or gaps in the argument, they are sincerely invited to come into the discourse with their experience and knowledge.

It is clear that an expert discourse does not change the course of events by itself. It is also clear that expert opinion may not be translated into social awareness, let alone political action, easily. The Working Group Bio-Resources however starts this discourse believing that there are worse starting points for transition than an expert discourse. The Working Group invites its members to actively partake in the wider societal discourse about bio-resource use and hopes that this internal discussion will help strengthen their arguments.

Part 1

Fundament of rational bio-resource utilisation

2 Setting the scene

2.1 The quest for a bio-based economy

The perspective of a bio-based economy can be considered as an important next step in achieving sustainable development. Sustainable development was firmly conceptualised and brought to political and societal agenda's by the Brundtland Commission and the Johannesburg World Summit on Sustainable Development in 2002. The Earth Summit in Rio de Janeiro in 1992 pushed the concept to global agenda's and is now a leading guidance in global, national and regional development.

The current bio-resources supply chain in Europe is very complex and still away from the best economic use of these materials for the greater good of EU society. One particular aspect of a bio-based economy is its link to a sustainable energy system. The European Union has framed its future energy policies in a number of documents covering a wide range of issues including *Europe 2020* (that year sees a 20% CO_2 reduction, a 20% increase in energy efficiency, and the utilisation of 20% renewable energy resources, EC, 2007a), describing Europe's ambition for a smart, sustainable and inclusive economy from overarching socio-economic perspective. The *Energy Roadmap 2050* (EC, 2011) describes EU energy strategy for the year 2050 and calls for even more ambitious goals of reducing the overall emission of greenhouse gases between 80 and 95 %.

Numerous international and European bodies are currently active to refine the strategies that will lead to achieving these goals. They include the International Energy Agency[1], the European Resource Efficiency Platform[2], the European Bio-Based Industries Initiative[3] and the European SET Plan Integrated Roadmap Working Group[4], among many others. This document aims to contribute to this discourse on the European level with particular focus on the challenges linked to the use of bio-resources.

2.2 Transition towards contested resources

Most political goals (e.g. the European Union 20-20-20 Goals) and plans (e.g. the European Union SET Plan, EC 2007b) call for dramatic increases in energy efficiency on the energy consumer side and in capacity of renewable energy technologies on the provision side of the energy system. The European Union Energy Roadmap 2050 as an example requires an energy demand drop between 32 and 41 % and an increase of the share of renewable resource based energy provision by at least 55 % in 2050 compared to 2005 (EC 2007a).

Although the increase in renewable energy provision will be shouldered by technologies drawing on different renewable resources such as hydro power, wind, direct solar energy, geothermal energy, wave and tidal energy, bioenergy is regarded as an important factor in the future energy mix. The IEA estimates that by 2050 bioenergy will contribute 160 EJ per year of primary energy to the global energy mix, covering roughly a quarter of the total primary energy supply. This compares to 50 EJ (and a share of 10 %) it contributed in 2009 to the global primary energy supply, more than tripling the amount and more than doubling its current share (IEA 2012).

[1] See www.**iea**.org [accessed Jan., 2014]
[2] See ec.europa.eu/environment/resource_efficiency/re_platform, [accessed Jan., 2014]
[3] See http://bridge2020.eu/, [accessed Jan., 2014]
[4] See http://setis.ec.europa.eu/set-plan-implementation/integrated-roadmap, [accessed Jan., 2014]

This increased energy demand however meets an already contested resource. By 2050 the world population will increase to between 9 and 11 billion people (from its current 7,2 billion), requiring at least 10^{16} kcal of food per year, an increase of over 40 % from a current value of $7*10^{15}$ kcal/a[5]. Besides, well entrenched industrial sectors, most notable pulp and paper production and construction, use already large amounts of biomass. According to the FAO the world consumption for industrial round wood will reach 2.436 $*10^9$ m³ wood raw material equivalent (WRME), 45 % up from the 2005 consumption of 1.682 * 10^9 m³ WRME.

Thus biomass is a heavily contested resource. One reason for this is that biomass is very versatile and can satisfy so many different demands.

On the supply side biomass is produced by plants collecting sunlight on the earth's surface and using it to convert atmospheric CO_2 into biomass, today predominantly on the available land area. Thus it is actually the land area that is the limiting factor. Some of the plant biomass is then converted into animal-based products, used almost exclusively for food.

The continually increasing human demands sketched above lead to a significant pressure on bio-resource production. This means that bio-resource as well as land-area utilisation will require a delicate balancing act in order to fulfil these demands in a reasonable and ethically acceptable way.

2.3 System change is needed

This balancing act requires substantial and system wide change. Evidences of a paradigm shift are already visible across the European energy system as regions and cities across Europe show clear signs of early transitional changes. It is in these regions, experimenting with new resources, technologies, organisations, and business models that deviate from the dominant energy systems that Europe must look for innovative new paradigms: *transition from below*. Early experiences suggest that the transition poses a multi-level governance challenge to the EU, from local level microeconomics to EU-wide policies and change management, and it is the integration of these measures that is most lacking at present.

[5] See e.g. http://www.tasteofsustainability.com [accessed Jan., 2014], based on FAO data

3 A unique set of resources

There seems to be no other group of resources that can fulfil such a wide variety of demands as bio-resources. There is however no other group of resources that entail so direct and large scale impact on society and the environment for its provision and that so clearly highlight the general conundrum of sustainable development, namely living with “limited infinity”. At the base of these statements lays the fact that bio-resources are the only form of resources that convert solar radiation into utilisable materials. This conversion requires as a basic production factor area, which is limited as our planet has a limited surface. Besides that it requires other ingredients, namely fertile environmental compartments (be they soil or water bodies) and enough material precursors, most notably water and carbon sources like CO_2[6].

Seen from the vantage point of converting solar energy into energy embodied in materials, the generation of bio-resources (mainly by the process of photosynthesis) is not a particularly efficient process. Maximum theoretical conversion rates of solar radiation into bio-resources (according to Zhu et al. 2008) are between 4.6 for the more common C3-plants (e.g. rice, wheat, potatoes) and 6 % for C-4 plants (e.g. maize, sorghum, millet, sugarcane). Practical conversion rates are at best 50 % of these theoretical values. Further conversion rates of plants to meat are between 5 to 50 % (see e.g. FAO 2006), making meat a particularly costly good when related to the natural solar income.

It is this low efficiency of converting solar radiation into useful energy from bio-resources (regardless if used for nutrition or technical purposes) that makes “living in limited infinity” particularly obvious: bio-resource generation rate is limited by the limitation of the production factors, most notably arable land and forest area. This rate may however be sustained over (practically) infinite time if human society learns to manage these production factors cleverly.

Human society is already a strong contender for this limited form of natural income. Beer et al. (2007) estimate Global Net Primary Production (NPP, the rate at which sunlight is converted into useful chemical energy, measured in the mass of carbon fixed by photosynthesis per year) to roughly 105 Gt/a, of which 53.8 % are allotted to terrestrial systems. Haberl et al. (2007) show that from the terrestrial NPP 23.8 % are already appropriated by man, be it by harvesting (53 % of this appropriation) or land use change (amounting to 40 % of the appropriation) or human-induced fires. They also point out that the overall impact of human activities reduces the NPP by almost 10 %. According to these authors it is far from certain that the current rate of appropriation is sustainable.

Limited generation rates are one aspect that makes bio-resources inherently contested commodities. Their versatility is another. From the vantage point of the energy sector and the chemical industry as well, bio-resources can fulfil every demand currently covered by various fossil (and nuclear) technologies: they may be converted in heat or electricity, fuel (transportation fuel in particular) or any chemical compound demanded by the market. In a time when fossil oil, the key resource for synthetic materials and transport fuels faces its production maximum and, together with all other fossil resources, comes under increasing environmental scrutiny as a culprit of global climate change, the versatility of bio-resources translates into increased demand from various sectors. This adds to

[6] Neither water resources nor carbon resources will be in the focus of this text, although references to the linkage between water and bio-resources will be discussed when appropriate.

the already strong competition for bio-resources between traditional users, in particular the food sector, firewood use and pulp and paper industry, to name the most important ones.

Land as a basic production factor for most bio-resources is strictly limited on our planet. This means that any competition for bio-resources will inherently end up as a competition for land, reiterating the importance of the regional and local level already mentioned above. On top of that different actors vying for bio-resources have different preferences regarding the form of resource the use: the food sector needs crops of various kinds, pulp & paper as well as construction industry need wood from forests, transport fuels presently need biofuel crops whereas the chemical sector has the broadest portfolio of resources. This leads to direct competition between sectors, such as the competition for crops between the food sector and bio-fuel industry, but also to a competition between different forms of land use. Forests providing resources for energy provision or pulp &paper industry may compete with fields that provide crops for food or bio-fuel if the land in question can support both forms of land use. Table 1 summarises the area resource globally available today on a per capita base.

Table 1: Available land per capita

Category	ha/cap today	ha/cap 2050
Sea	5.17	3.4-4.79
Total land area	1.86	1.22-1.72
Agricultural land	0.7	0.46-0.65
Arable land & permanent crops	0.22	0.145-0.19
Pasture	0.48	0.315-0.415
Forest	0.58	0.38-0.49

Table 1 also shows that available land area will decrease until 2050 by a factor between 1.08 and 1.5 taking population growth into account. Factoring in the decrease of area for the production of bio-resources from other reasons (e.g. settlements and land degradation) that currently stands at 1.5 % annually makes the lower boundary of available land per capita in 2050 more probable. This will further aggravate the already noticeable competition between different forms of land use.

Decisions about land allocation and land use are inherently political, involving the entirety of society. Different actors will bring other aspects than economic utility of biomass to the table and other functions of land and land cover than their value for nutrition, energy and raw material provision will have to be considered. Cultural landscape offer a strong base for identification with the spatial context of society[7], major changes in the land-use pattern will therefore cause intensive societal discourse. It may also interfere with other important economic sectors such as tourism. On top of that the form of land-cover will have direct consequences on many ecological parameters like biodiversity, long term soil quality, fertility as well as climate. Ripl and Wolter (2002, 2005) have discussed the severe impact of agriculture on the nutrient content of soils and the degradation of water bodies caused by nutrient transport from soil by run-off water. Ripl (1995) and Hildemann (1996) discussed the impact of different land cover forms on the local water cycle, surface

[7] See e.g. the final report of the EU Project REGIONET, accessible via http://www.iccr-foundation.org/projects/regionet

temperatures as well as micro and macro climes. Taken together their results show that our current form of intensive agriculture depletes soils of ionic nutrients and prominently adds to increased surface temperatures while forests close local water cycles more efficiently, resulting in greatly reduced surface temperatures and retention of nutrients.

Bio-resources are not only limited and seriously contested goods; they also demand other critical resources for their generation. Besides having a strong impact on local and regional water cycles agriculture is also the single most important consumer of fresh water. From the 3,862 km³ of water utilised by man in 2003[8] 2,710 km³ (or 70 %) where used by agriculture. The provision of crops in particular also requires large amounts of fertilizers causing environmental problems as part of them are lost to ground and run-off water. The FAO (2008) reported a demand of 127,820,000 t of nitrogen as fertilizer in this year and estimates for 2012 are even 8.5 % higher. This does not only add considerably to eutrophication of water bodies, it also requires large amounts of energy as even in state-of-the-art production plants 1 t of nitrogen for fertilization requires about 40 GJ of energy, provided usually via natural gas.

Like with all other resources however primary consumption and hence pressure on land and other basic resources, is not solely dependent on societal demand. The other major factor is efficiency of use. The longer a bio-resource once harvested is kept in use, the more functions it fulfils within its life cycle the lower will be the overall pressure exerted by society on the primary resource land. As land is strictly limited, efficient and sustainable management of bio-resources, their by-products and wastes becomes an urgent requirement for sustainable development.

Summarizing the arguments of this chapter leads to following conclusions that are important for finding the right balance for utilising bio-resources:

- Bio-resources are a form of the natural income of solar radiation that is severely limited by crucial production factors, most notably the available surface area of our planet and the productivity of its ecosystems;
- Bio-resources induce considerable ecological impact in their generation; human societies appropriation of these resources may already been at its sustainability limit.
- Bio-resources are extremely versatile with regard to their use. They are the only source of food for human society and already provide energy and raw material for well-established industries but may also be converted into any product currently made from fossil resources.
- In an era of emerging economic and environmental limitation on the use of fossil and possibly nuclear resources, the pressure on the versatile but limited bio-resources will definitely rise.
- Efficient management of bio-resources once harvested is a major leverage to increase the service society can collect from the limited resource of land.

[8] For statistics on water use see the web-page of the FAO Aquastat:
http://www.fao.org/nr/water/aquastat/dbase/AquastatWorldDataEng_20101129.pdf

4 Dynamic markets and intertwined value chains

Bio-resources already support a considerable part of European economy. Basic data for the major economic sectors are summarised in Table 2.

Taken as a whole, bio-resource based business sectors account for more than 4 % of European gross added value and ca. 8 % of jobs.

The bio-resource based sectors have, similarly to fossil resource based sectors, strongly intertwined supply and value chains. This is the result of a common base resource, namely fertile land. As this resource may not be expanded easily since it is itself under pressure from growth in land for settlements and infrastructure, any increase in the share of bio-resources a sector is using leads to volatility of markets. Currently the growth of the bio-energy sector is a major cause for market volatility. As can be seen from estimates for available area in 2050 from Table 1 this trend is bound to become stronger in the coming years.

Table 2: Economic parameters for major bio-resource sectors in the EU 27[9]

Sector	Turnover [bil €/y]	Gross Added Value [bil €/y]	Employes [1.000]	Business entities [1.000]
Agriculture & Forestry	353	168	12.200	7.300[10]
Food	968	199	4.800	310
Pulp & Paper	166	41	715	19
Bio-energy	n.a.	35	875	n.a.

Table 3: Estimation of total contribution expected from bioenergy (ktoe)

	Bioelectricity				Biomass for heat and bio-heat				Biofuels			
	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
EU 27	5936	9737	14344	19697	52522	61782	72880	89756	2821	13819	19460	28859
Austria	243	406	415	443	3033	3415	3463	3607	35	330	370	490
Belgium	154	259	512	949	477	682	1178	2034	0	329	497	789
Bulgaria	0	0	56	75	724	734	929	1073	0	30	115	196
Cyprus	0	3	7	12	4	18	24	30	0	16	22	38
Czech Republic	62	166	414	531	1374	1759	2248	2517	3	243	438	623
Denmark	279	324	519	761	1759	2245	2526	2643	0	31	247	261
Estonia	3	21	30	30	505	612	626	607	0	1	35	89
Finland	831	696	850	1110	5490	4990	5810	6610	0	220	420	560
France	328	378	902	1476	9153	9953	12760	16455	403	2715	2925	3500
Germany	1206	2818	3619	4253	7260	9092	10388	11355	1742	3429	3070	5300
Greece	8	22	43	108	951	1012	1128	1222	1	107	386	617
Hungary	0	168	193	286	0	812	829	1272	5	144	250	506
Ireland	10	30	76	87	183	198	388	486	1	134	299	481
Italy	402	743	1179	1615	1655	2239	3521	5670	179	1016	1748	2480

[9] Most data from *Situation and prospects for EU agriculture and rural areas;* http://ec.europa.eu/agriculture/publi/situation-and-prospects/2010_en.pdf [October 2013, data refer to 2010]. Data on Pulp & Paper Industry from http://ec.europa.eu/enterprise/sectors/wood-paper-printing/paper/competitiveness/index_en.htm [October 2013, data refer to 2010]. Data on Bio-energy from Frauenhofer ISI: Final report of EmployRES, 2009, data refer to 2005

[10] Agricultural holdings larger than 1 European Size Unit

Latvia	4	6	57	105	1114	1020	1147	1392	3	39	39	46
Lithuania	1	13	65	105	686	663	879	1023	4	55	109	167
Luxembourg	4	6	17	29	19	23	50	83	1	42	81	216
Malta	0	1	12	12	0	1	2	2	0	0	0	0
Netherlands	433	514	1148	1431	609	684	778	878	0	307	567	834
Poland	125	518	851	1223	0	3911	4227	5089	43	966	1327	1902
Portugal	170	206	289	302	2507	2179	2339	2322	0	281	429	477
Romania	0	0	0	0	3166	2794	2931	3876	0	224	363	489
Slovakia	3	52	116	147	358	447	576	690	0	82	137	185
Slovenia	10	26	54	58	445	415	495	526	0	41	79	192
Spain	228	388	513	861	3477	3583	4060	4950	258	1703	2470	3500
Sweden	651	914	1177	1441	7013	7978	8622	9426	144	340	528	716
UK	783	1060	1229	2249	560	323	958	3914	nm	996	2510	4205

Data Source: AEBIOM Annual Statistical Report 2011; www.aebiom.org

From the point of the European Comission bioenergy development is adressed in one of the seven SET Plan Roadmaps on Low Carbon Energy Technologies[11], calling i.a. for a share of 14 % of sustainable, cost competitive bioenergy in the European energy mix, as well as in the SET Plan Materials Roadmap[12].

Table 3 shows estimates for the development of bioenergy until 2020 in the EU. In total biomass use for energetic purposes will, according to this estimate, rise by a factor 2.25 in the 15 years from 2005 to 2020 with a necessary workforce by 2020 of almost 2 Mio. fulltime equivalent employees- The time between 2020 and 2050 may see a further doubling of the energy from bio-resources, leading to even more pressure on these resources.

This table shows that the increase of bioenergy utilisation will be uneven in different applications. Whereas electricity from bio-resources may increase by a factor of 3.3, heat provision will only increase by 70 %, although with the highest increase in absolute numbers. The most dramatic estimated increase relates to biofuels, with a factor of 10!

Summarising the arguments of this chapter shows that

- Bio-resource already support a considerable part of Europe’s economy
- The value and supply chains of these sectors are strongly intertwined
- An increase in the share of bio-energy in particular adds dynamic to the whole market

[11]See http://setis.ec.europa.eu/about-setis/technology-roadmap/the-set-plan-roadmap-on-low-carbon-energy-technologies [last consulted February 2014] for further details.

[12] See http://setis.ec.europa.eu/activities/materials-roadmap/ [last consulted February 2014] for further details.

5 Resources with logistic constraints

Bio-resources are characterised by provision with much lower spatial density than other resources. As an example for this difference consider the Ghawar oil field in Saudi Arabia, with a production of roughly 5.000.000 barrels of crude oil per day on an area of 280 x 30 km. This calculates to an annual "yield" of 2.173 barrels per hectare, representing an energetic yield of roughly 3.700 MWh/ha.a. This may be compared to a miscanthus field with 17 t/ha.a yield of fresh material with a lower heating value of 5 kWh/kg. This field will provide an energetic yield of about 85 MWh/ha.a, by a factor of 43 lower than the oil field. This difference makes bio-resources inherently de-central in their provision compared to the by and large point source provision of fossil resources. As a consequence the logistic to collect these de-centrally provided bio-resources will become important.

Resource collection becomes even more decisive given the difference in logistical parameters between fossil and bio-resources. Table 4 shows a comparison of humidity, transport density and energy content for some example resources.

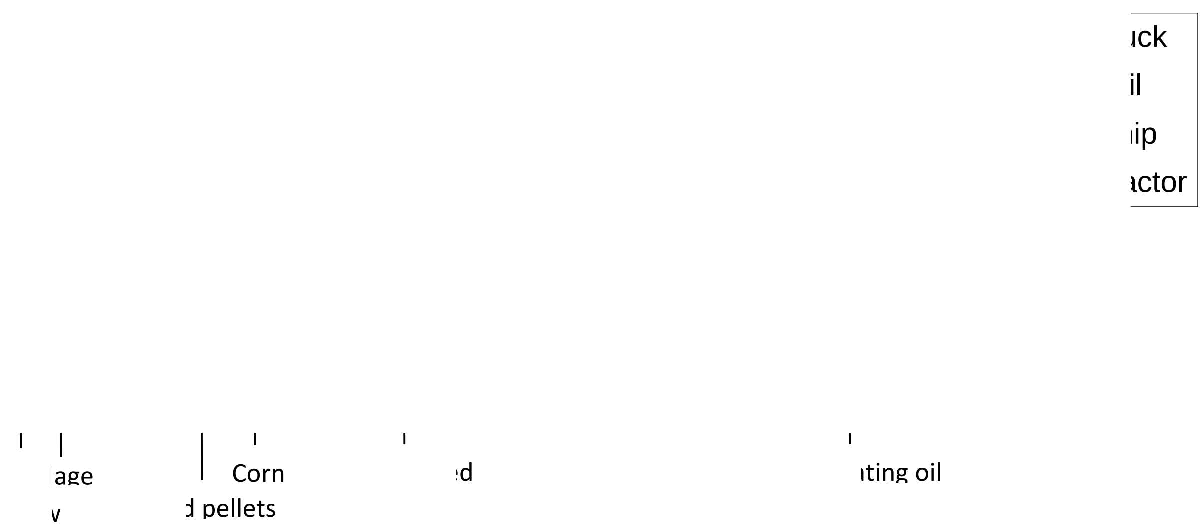
This table shows that bio-resources are characterised by high humidity and/or low transport density and generally lower energy content. In many practical cases therefore transport volume will become limiting for the collection logistic of these resources. The differences between fossil resources, represented here by light heating oil and bio-resources are poignant: there is a factor of 24 between straw and light heating oil with regard to their energy density.

Table 4: Comparison of logistic parameters for fossil and bio-resources (adapted from Gwehenberger & Narodoslawsky, 2008)[13]

Conversion	Material	Humidity [%w/w]	Energy content [MJ/kg]	Density [kg/m³]	Energy density [MJ/m³]
Incineration	Straw (grey)	15	15	100-135	1.500-2.025
	Wheat	15	15	670-750	10.050-11.250
	Rape seed	9	24.6	700	17.220
	Wood chips	40	10.4	235	2.440
	Split logs (beech)	20	14.7	400-450	5.880-6.615
	Wood pellets	6	14.4	660	9.500
Biogas production	Grass silage	60-70	3.7	600-700	2.220-2.590
	Corn silage	65-72	4.2	770	3.230
	Organic municipal waste	70	2.4	750	1.800
	Manure	95	0.7	1000	700
	Light fuel oil	*0*	*42.7*	*840*	*36.000*

[13] For dry materials the lower heating value was taken into account, for wet materials lower heating value of biogas from digesting the materials was taken as representative. This leads to comparable energy quality (i.e. exergy) levels. The disadvantage of wet resources must be put in perspective: biogas has a much broader range of applictions than heat generated by incineration.

Figure 1: Specific energy to transport a unit of energy



The results from Figure 1 have dramatic implications for the logistical structure of bio-resource utilisation. Collecting resources must not use a large part of the value (i.e. energy content) the good in question comprises if its utilisation shall become economically viable. If we set the limit of the energy used to transport a resource to its utilisation site arbitrarily to 1 % of the contained energy, we obtain the following results:

- In case of manure, straw and corn silage 1 % of the contained energy will power a tractor (as the most common short distance means of transportation on farms) 5.7, 12 or 18 km respectively;
- 1 % of the energy contained in wood chips and split logs will power a truck for 40 and 100 km respectively;
- For wood pellets and corn a train will go for 475 and 525 km respectively using 1 % of the transported energy content;
- An ocean going ship loaded with crude oil however will travel 7.800 km with 1 % of the energy contained in its cargo.

These numbers highlight the spatial context of bio-resource use: whereas it is fully rational to establish a global fossil economy as transport from source to utilisation plays almost no role, the use of bio-resources must become regional and possibly even local. This is particularly true if low grade bio-resources or bio-wastes are to be utilised for energy or material provision, as they are characterised by especially disadvantageous logistic parameters.

There are many implications resulting from these crucial logistic properties of bio-resources that will be dealt with in the following chapters. One particularly interesting aspect concerns the technological approach to deal with large volumes of resources. In a fossil based economy the solution to more resources to be utilised is bigger plants: as bigger plants are more efficient and less costly than smaller plants following the "economy of scale", building bigger saves money and usually ecological impact.

This option is less attractive for bio-resources as bigger plant capacities also mean longer transport distances for collecting resources and re-integrating wastes. While economy of scale can still be an option for primary bio-resources, it certainly becomes problematic for utilising secondary bio-resources either as sole feedstock or for provision of energy. Gwehenberger et al. (2008) argue that de-central bio-ethanol plants powered by harvest residues show dramatically decreased ecological pressures compared to large scale conventional plants but that this advantage decreases when plant capacities exceed a certain size. In this case economy of scale runs contrary to ecology of scale. Rather than building larger plants the approach for secondary bio-resources may well be to design smaller components for serial production (thus reducing investment costs) and combine them into technology systems optimally adapted to the spatial context.

Summarising the arguments from this chapter, bio-resources are characterised by

- Low yield per hectare compared with fossil resources, making them classical de-central resources;
- Disadvantageous logistic properties (low densities, high humidity)-

This requires taking logistical constraints along the whole value chain of bio-resources into particular consideration

6 Appropriate resources for a bio-economy

Bio-resources are the basis for human nutrition. The actual utilisation of bio-resources for nutrition is strongly dependent on diet and life style parameters. As wealth in large countries like China and India as well as in Africa increases the diet of the global population may shift to a larger fraction of meat. Coupled with the still on-going global population growth it can lead to a considerable increase in the demand for meat. Some estimates[14] put the increase in per capita meat consumption from 2005 to 2050 at almost 68 % (from 41 to 68,8 kg/(cap.y)) and the total global meat consumption increase over the same period at 135 % (from 266 Mt/y to 624 Mt/y). With low conversion rates from solar radiation to nutritional energy, rising meat consumption puts a particular strain on bio-resources.

Besides an increased meat consumption waste along the food provision chain is another factor associated with this societal service of bio-resources. A study commissioned by the FAO[15] estimates that 1.3 Gt/y edible food, produced on roughly one third of the available agricultural area, will perish or be wasted on its way from the farms to the consumer. The study points out that this loss and waste is strongly dependent on the life style, as it is an order of magnitude larger in wealthy industrialised countries (95-115 kg/(cap.y) in Europe and North America) compared with Sub-Saharan Africa and South East Asia (6-11 kg/(cap.y)).

There is a wide variety of bio-resources. This does not only concern the wide variety of plants and animals that man has domesticated for his purposes. It also applies to by-products and wastes from industrial and societal processes using primary bio-resources.

The intense competition for bio-resources (and hence for fertile land) applies in particular to the relative small number of primary agricultural crops and wood from forestry, leaving the oceanic fish resources mainly used for food out of consideration for a moment. It is obvious that waste along the food provision chain as well as increasing meat consumption seriously aggravates this competition for primary bio-resources, in particular from fields and grass land. Reducing either of them would allow feeding an increasing world population while at the same time freeing valuable resources for a sustainable bio-economy.

Table 5 summarizes some of these primary resources and gives an overview on the order of magnitude of their yields, the main content and the industrial sectors competing for their use with the food and feed sector that uses all of these resources.

Table 5 shows that yield of agricultural and forestry products vary widely between the crops listed. Yield of a particular product may on top of that vary according to region and climate. The share of the valuable content of crops varies widely. A case in point is the comparison between potatoes and corn: although potatoes have a much larger fresh mass yield, the mass of starch harvested by either corn or potatoes per hectare is comparable. The reason is the high water content of potatoes that drives up the fresh material yield. The order of magnitude for yields in Europe of valuable, high

[14] T. E. Elam calculates in his treatise *Projections of Global Meat Production Through 2050* meat consumption based on global GDP and population growth. Accessible via: http://www.farmecon.com/Documents/Projections%20of%20Global%20Meat%20Production%20Through%202050.pdf

[15] See: Food Wastage Footprint- Impact on natural resources; Study commissioned by the FAO 2013, accessible via http://www.fao.org/docrep/018/i3347e/i3347e.pdf [last consultzed April 2014]

energy content substances is somewhere around 1 to 4 t/(ha.y) for oils and fats, 5 to 10 t/(ha.y) for starch may reach 15 t/(ha.y) for sugar and cellulose. More complex substances (e.g. essential oils, pigments etc.) have yields orders of magnitude below these numbers, in the range of a few kg to hundreds of kg/(ha.y).

Table 5: Contested primary bio-resources

Bio-resource	Origin	Yield [tFM/(ha.y)]*	Main content	Yield for main comp. [t /(ha.y)]	Current competition: f= food; b =bio-fuel; c= chemicals; e= energy; p= pulp&paper
corn	fields	10-15	starch	6-9.5	f/b /c
wheat	fields	8	starch	4.5	f/b /c
potatoes	fields	30-50	starch	5-8.5	f/b /c
rape	fields	2-4	oil/protein	0.9-1.8/0.5-1	f/b /c
sun flower	fields	2.6-3.6	oil/protein	1.3-1.8/0.5-0.7	f/b /c
jatropha**	fields	4	oil	1.2	b/c
palm fruits**	plantation	15-22	oil	4-6	f/b /c
sugar beet	fields	70-95	sugar	10-16	f/b /c
sugar cane**	plantation	40-100	sugar/cell.	6-15/6-15	f/b /c
grass	grass land	6-12	cellulose	2.5-5	f/e
miscanthus	fields	12-28	cellulose	5-13	e/(c/p)
wood	forest	3.5-6	cellulose	1.3-2	c/e/p
short rotation wood	fields/grass land	10-18	cellulose	3-6	e/(c/p)

*….FM = fresh mass

**..plants growing outside Europe (for comparison only)

This table shows also that the nature of the competition varies among different agricultural and forestry products. Whereas competition for starch, sugar and oil containing crops, with the exception of jatropha, is fierce and involves the food, energy (bio-fuel) and chemical sector, the competition for cellulose containing bio-resources is mainly between industrial sectors and the energy sector. In terms of land use there is a certain overlap between cellulose containing bio-resources and those containing other substances as high yield cellulose crops (e.g. miscanthus, short rotation plantations) also require prime farmland. Given the strong competition for crops from fields and the absence of the food sector as a major competitor for forest products, there is a noticeable pressure to change the land use of woodlands, marshes and to a certain extent grassland towards fields. As described above, such a change entails risks in particular regarding the water cycles, long term soil fertility and climate as the cutting of local/regional water cycles leads to high surface temperatures and may enhance extreme weather conditions.

There are however other kinds of bio-resources that is outside the current pattern of competition: secondary bio-resources that are by-products or wastes from agricultural, industrial processes and tertiary bio-resources that result from societal use of bio-resource based products such as waste paper or waste wood. Furthermore there are additional bio-resources that use land that is underutilised or otherwise not cultivated. The use of these types of bio-resources does in general not add to the direct competition for land although it may influence the fertility of land. In general the use of secondary and tertiary bio-resources is either in the form of a cascade, prolonging the value chain of a primary resource within society, or parallel to a valuable crop by using parts of plants that are usually not entering the markets such as straw and corn cobs.

Table 66 shows some of these secondary bio-resources. As a rule of the thumb one can estimate their overall global flow to be in the order of magnitude of the current flow of agricultural products. These bio-resources therefore offer interesting options for the provision of bio-energy and bio-materials in future.

Table 6: Examples for secondary, tertiary and additional bio-resources (adapted from Gwehenberger & Narodoslawsky, 2008)

Raw material category	Origin	Material (examples)
Secondary	Agricultural wastes	Manure
	Residues from industries	Slaughterhouse residues
		Tallow
		Oil seed cake
		Glycerol from bio-diesel prod.
		Dried distillers grain
		Black liquor from pulping
		Sugar beet chips
		Pomace
		Tanning residues
	Residues from energy provision	CO_2
		Ashes
	Harvest residues from agriculture/forestry	Low quality forest residues
		Straw from corn, cereals, oil seeds, …
		Leafs from beets, potatoes, …
		Cuttings from wine yards, orchards, …
Tertiary	Residues from society	Waste paper
		Waste plastic
		Organic municipal waste
		Garden cuttings
		Used vegetable oil
		Waste water
Additional	Underutilised bio-resources	Grass
	currently uncultivated land	Micro algae

Competition for, availability of and restriction for the use of these resources again vary widely. For some of them (e.g. tallow, straw, waste paper etc.) there exists already a certain market. For these resources it will be crucial if any innovative utilisation form (e.g. ethanol from straw) will lead to higher value for the resource and if their current service may be provided by other means at lower economic, environmental and social costs.

A case in point is harvest residues. Before contemplating the use of these resources it is imperative to ensure that their withdrawal is sustainable, generating at least constant or improved fertility. This requires careful management of soil quality by establishing maximum withdrawal rates and possibly by returning nutrients from other sources, namely wastes at the end of utilisation cascades such as ashes and manure.

A challenge that is common to all the secondary and tertiary bio-resources described here (and also to a large part of primary and additional bio-resources) is the design and operation of an optimal logistical system for collecting the resources, distributing the products and possibly re-integrating waste flows into the environment.

Summarising the arguments brought forward in this chapter points out that

- Primary bio-resources are highly contested, although the nature of this competition varies according to the sectors that may utilise them;
- Reducing waste along the food value chain and using meat in a conscious way are potent ways to secure global nutrition and may free primary bio-resources to support a sustainable bio-economy;
- The fiercest competition is for crops from fields, leading to a pressure to change the land use in particular of grass land, wet lands and forests, resulting in considerable ecological risks;
- Further increase of bio-resource supply that does not increase the competition for food must focus on secondary, tertiary and additional bio-resources;
- The use of residues from the production of primary bio-resources must be subject to considerations regarding the preservation of fertility of the land.

7 Products and services from bio-resources

7.1 Social services of bio-resources

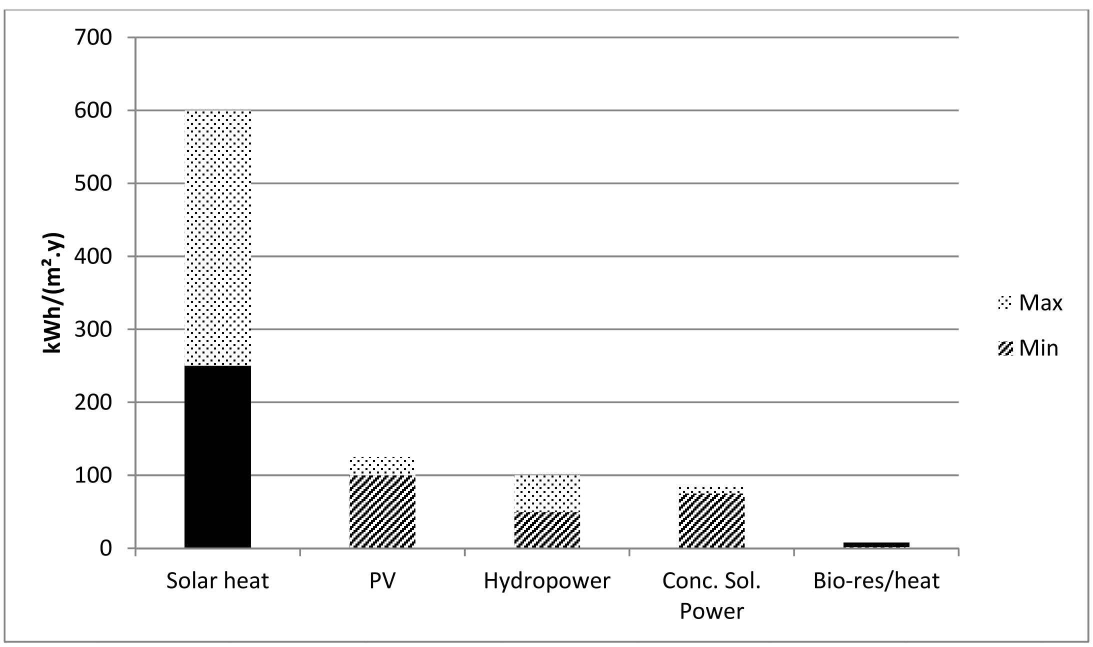
There is no doubt that the main societal service of bio-resources is to provide food for the global population. Bio-resources currently have a monopoly on this service. Feeding the increasing world population is a pre-requisite of human development and the use of primary bio-resources for this purpose is without alternative.

Bio-resources are inherently linked to rural regions. Although urban centres will become more prominent as suppliers of secondary bio-resources in the form industrial by-products and tertiary resources resulting from societal consumption, rural regions will remain the provider of primary bio-resources and secondary bio-resources in the form of harvest residues and by-products of agriculture. Bio-resources can only be utilised sustainably when they also provide the service of a sufficient base for the livelihood in these rural regions.

7.2 Economic services of bio-resources

Bio-resources are no drop-in for fossil raw materials. They transform solar radiation at a low efficiency, requiring a large share of the ultimate primary resource, fertile land, for their generation. Figure 2 shows, that conversion of bio-resources to useful energy trails that of other renewable energy sources by far on a kWh per hectare base.

Figure 2: Conversion efficiency for solar radiation into useful energy (data for hydropower represent area for reservoirs)



Wind power, solar thermal energy and photovoltaic will become major suppliers of electricity and electricity will become more prominent in any sustainable energy system (see e.g. European SET Plan Roadmap). All these technologies convert solar energy much more efficiently into electricity than technologies based on bio-resources can do. All these sources however are either periodically or intermittently available. The more these resources will shape the energy system, the less room there is for conventional base load technologies like nuclear and large fossil based power plants. This requires other approaches to stabilise distribution grids, in particular for electricity. Besides management of power demand (by *smart grids*) the use of energy storage or material energy carriers (both fossil and bio-based) that pick up the gap between intermittent electricity provision and demand will become necessary. A service provided by bio-resources in a sustainable economy may therefore be to contribute to the task of stabilising energy distribution grids, especially for electricity.

In the same line runs the argument for transport fuel. Currently this service is overwhelmingly provided by fossil oil, with the global share of bio-fuels currently at about 3 %[16]. Fuel for transport is inherently a storage issue. In addition to the arguments given above, considerations of energy density, weight of the storage system and range have to be taken into account. As more and more people concentrate in cities (the WHO expects 70 % of the world population living in cities by 2050[17]) the overall pattern of transport may change considerably, with public transport, bicycles and electric vehicles providing mobility in urban regions. Long distance individual mobility, air traffic as well as ships will however require stored energy with high energy density, quick charge and low emissions. Bio-fuels are a viable alternative for this service.

Still another service relevant for economic sustainability is the provision of heat. Low temperature residential heat can be easily provided sustainably by solar thermal units, ground heat pumps (using electricity for their operation) and off-heat from thermal electricity provision or industry (distributed via district heating grids in urban areas). Low temperature heat may also be stored cheaply, with costs as low as 0.1 € ct /kWh. The situation is however different for high temperature industrial heat. This service is currently covered by coal and natural gas, together with electricity for special applications (e.g. steel smelters). Alternatives on the base of renewable resources are however scarce. This opens the way for processed bio-resources like cleaned biogas and char coal that may contribute to the provision of high temperature industrial heat.

Bio-resources together with carbohydrates derived from sequestered CO_2 and hydrogen produced by surplus electricity are the only renewable sources for organic material. They may therefore be used for generating plastic as well as high-tech synthetic material. Today the global production of plastic reaches around 280 Mt/y[18]and thus is an order of magnitude lower than current human utilisation of wood. Current synthetic materials industry is supplied with fossil resources. Major increases in plastic production will have to cut into other utilisation pathways for crude oil if its production stagnates or even declines. One interesting alternative is to use bio-resources to pick up the increasing gap between synthetic materials demand and crude oil refining by-products supply.

It goes without saying that bio-resources will keep their role as feedstock for those industries that already now are based on these raw materials. The most prominent sectors here are pulp & paper,

[16] Data from IEA, accessible from http://www.iea.org/topics/biofuels/, [July 2013]
[17] Accessible from http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/, [July 2013]
[18] Data from Plastics Europe, accesible from http://www.plasticseurope.org/information-centre/press-room-1351/press-releases-2012/first-estimates-suggest-around-4-increase-in-plastics-global-production-from-2010.aspx, [July 2013]

construction as well as smaller volume industries in terms of resource utilisation, such as pharmaceuticals, cosmetics and wellness products, speciality lubricants and many others.

7.3 Environmental services of bio-resources

When discussing environmental services of bio-resources the main argument is almost always their contribution to climate gas emission reduction. Following the argument given above, bio-resources are however no general solution for sustainable energy systems and the largest share of energy services in future will be shouldered by other renewable energy technologies and a marked increase in energy efficiency. This puts the climate saving service of bio-resources into perspective.

The provision of bio-resources is arguably the broadest and most widespread human impact on the ecosphere. It changes landscapes as well as the quality of soils and water bodies, disturbs natural habitats and water cycles. Agriculture and forestry are responsible for managing fertile land and thus the very livelihood of man as well as all other creatures. The most important ecological service of bio-resources is therefore to maintain or even improve by their generation the long term productivity of fertile land and guarantee the co-evolution of the all non-human natural partners. This requires careful management of soil quality and nutrients as well as considering water cycles and providing sufficient habitat to maintain bio-diversity.

Table 7 summarizes these services as well as listing alternatives that may contribute to those services, too.

Table 7: Bio-resource services for sustainable development

Type of service	Service	Alternatives
Social	Nutrition	None
	Jobs and development for rural regions	None
	Social stability for rural regions	None
Economic	Stability for energy distribution grids	Smart grids, hydro power, pumped hydro power, hydrogen*, compressed air energy storage, (fossil resources)
	Transport fuel	Electricity (using battery storage), hydrogen, synthetic fuels, (fossil resources)
	High temperature industrial heat	Hydrogen*, (fossil fuels)
	Feedstock for synthetic materials and plastics	Sequestered CO_2 plus hydrogen*, (fossil resources)
	Feedstock for conventional bio-based products	None
Environmental	Reduction of greenhouse gas emissions	Wind and hydro power, solar thermal systems, photovoltaic, oceanic power, geothermal energy
	Preserving soil fertility	None
	Preserving water and nutrient cycles	None
	Preserving bio-diversity	None

*...Hydrogen may be produced sustainably by electrolysis using surplus electricity from renewable sources.

Part 2

Aspects of the transition to a rational bio-economy in Europe

8 Leadership, change agents and system change

8.1 Top-down: Guiding the transition process

Climate change, security of supply and sustainability in combination with the establishment of the internal EU energy market initiated change and dynamics in the European energy scenery and policy which is still continuing. These dynamics are diverse and complex and are expected to affect the fundamentals of the technological and regulatory architecture of the energy and resource systems of the EU (Egenhofer et al., 2011; IEA, 2012). Currently the European Union is in the process of developing the energy technology policies needed to respond to the energy and innovation challenges Europe is facing in the global competition. The Strategic Energy Technology (SET) Plan, in the European Commission's own words, is the "technology pillar of the EU's energy and climate policy", "a blueprint for Europe to develop a world-class portfolio of affordable, clean, efficient and low-emission energy technologies"[19].

Governments, industry, knowledge institutions and civic society need to provide leadership for this change. Several energy scenarios (Shell, 2008, IEA 2012a, IEA, 2012b) point to a fundamentally changed energy system amounting to a paradigm shift in how our society is powered in future. According to the International Energy Agency's Energy Technology Perspective, energy policy needs to take the entire energy system into focus, since energy technologies interact (IEA 2012). The need for a system perspective is also stressed in the academic literature on transitional change and transition management[20]. In the Netherlands the transition management approach has been practiced intensively between 2000 and 2008 (Rotmans, 2011). Other countries like the UK and Finland are adopting the transitional change perspective in energy and beyond (Hoppe and Arentsen, 2012).

8.2 Bottom-up: municipalities and regions as agents of change

Top-down guidance of transition is however not sufficient. This is why a bottom-up approach to drive the bio-economy forward, involving the ordinary citizen in taking ownership, responsibility and most importantly pride in their efforts towards a sustainable environment is necessary.

Municipalities[21] and regions[22] are gaining significance as strategic and operational actors in addressing some of Europe's grand challenges. Increasing awareness of their importance and significance have strengthened their roles all over Europe, leading to increased independence, identity, and influence in the multi-level governance system of the EU. Energy transition, the transformation towards a bio-economy and the rational use and preservation of their natural endowment is a core focal point and domain for action in regional governance and bio-resources are considered a true regional asset, to be utilised for the benefit of regional socio-economic development.

[19] Cited from Egenhofer et al., 2011
[20] The academic journal *Research Policy* is an important platform of the transition scholars.
[21] See the activities of the European Energy Cities on http://www.energy-cities.eu/ [accessed April 2014]
[22] See e.g. the Regions 202020 network on http://regions202020.eu/ [accessed April 2014]

Energy as well as bio-economy ambitions of the EU are multi-level strategic challenges involving EU, national, and regional layers of governance. As the authoritative regulatory body, the EU is at the top level in addressing these challenges, but innovation and change mostly incubate and emerge at the regional and local industry level. Grassroots initiatives and developments, local and regional authorities, industries and organizations are picking up the challenge of a low carbon society system at a regional scale (Rogers, Jet al. 2012; Seyfang and Haxeltine 2012; Späth and Rohracher 2012). The local and regional initiatives are often energy focused and share an energy transition perspective from below. Communities, municipalities, provinces and regions all across Europe share the ambition to realize a low-carbon energy system in their own environment (Hoffman and High-Pippert 2010). Innovating and sustaining the local and regional economy is a core driver in these processes. Until now the initiatives have launched regional dynamics by public authorities/governments, industries and knowledge/civil organizations collaborating in effectuating the local and regional energy ambitions[23]. It is in the smaller regional context where new resources, technologies, organisations, and business models are developed and implemented, providing innovative technologies and energy services in response to critical need. This transition from below is challenging the entrenched large-scale energy and industrial systems in design, technology, organisation and functional efficiency.

Neither top-down nor bottom-up approaches however can be completely successful in their own right but combining these approaches can provide significant synergies and change agents, can energise the ordinary citizen in actively participating for their own and the common good.

8.3 EU Citizens Perspective

When looking at the bio-economy in general one can ask why the ordinary citizen would be interested in it. There are many answers from the altruistic right down to the completely self-centred point of view. Some people are interested only in financial considerations to the exclusion of anything else; if something doesn't save or make money then no interest is shown despite perhaps significant environmental benefits. On the other hand there are also people who are interested only in establishing a bio-economy regardless of the financial dividend. There is of course a middle ground where it can be suggested that the majority of people would like to be and that can be where money is saved for example on energy costs whilst at the same time delivering a positive environmental impact.

So at a very basic level the financial, social and environmental costs and benefits of the bio-economy need to be considered and made transparent especially to the ordinary citizen who in these current harsh economic times may have little alternative but to exercise choices detrimental to the environment and simply stay in the business-as-usual mode. There will always be early adopters of new ideas and technologies and this process needs to be encouraged and diversified to the EU population at large so that everyone sees the need and benefit of establishing a bio-economy.

23 See for instance the overview of initiatives in CEPS, GREENING EU CITIES THE EMERGING EU STRATEGY TO ADDRESS CLIMATE CHANGE, Brussels, 2010.

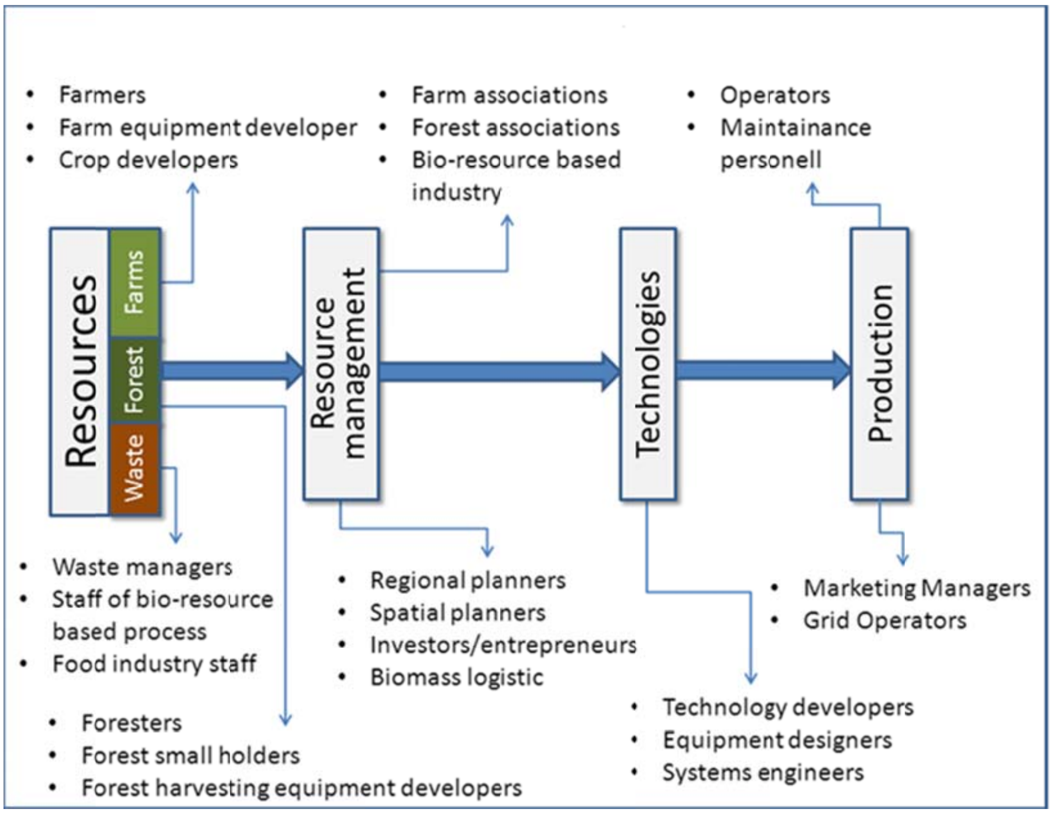
9 Research challenges of bio-economy transition

Bio resources are already widely applied, but much more efforts are needed to integrate the full potential of bio-resources as a society's sustainable resource base. Research and innovation is the key entrance point here and should cover a range of related themes and topics, covering the technical and non-technical challenges involved. This chapter provides an overview of the research and innovation needs to address these challenges.

9.1 Non-technical research and innovation challenges

The value chain of technical bio-resource utilisation comprises a variety of actors and stakeholders from different sectors, with different background and diverging interest. Figure 3 shows a simplified scheme of these different stakeholders in the value chain.

Figure 3: Stakeholders in the (technical) bio-resource utilisation value chain



The research and innovation challenges are incorporated in each part of the chain separately as well as in the chain as a whole. The non-technical research and innovation agenda addresses, among others, societal acceptance of a bio-based economy, governance issues involved in implementation, new business chains and models, logistics, learning and knowledge diffusion, energy planning and landscape development. The next paragraphs will highlight the themes and topics which are part of the non-technical research and innovation requirements. We first discuss the separate parts of the chain and end with the challenges involved in the whole chain.

9.1.1 Non-technical research regarding bio-resource generation

Sustainable use of bio-resources requires management of the competition between services provided by these resources. All types of landscapes may provide the natural foundation of bio-resources based services. This means that research must elucidate the contribution that different elements of natural as well as cultural landscapes and land-use patterns provide for the services that are derived from bio-resources. The challenge here is to combine deep disciplinary research that helps to gain insight into the natural functions of eco-systems as well as the interaction between humans and landscapes in their psychological and socio-economic dimension with the systemic knowledge that is necessary to understand the dynamic of the impact of bio-resource utilisation on nature, society and human psychology.

For secondary and tertiary bio-resources the issue is their optimal utilisation pathway to maximise their service. This requires further development of a sound scientific framework that allows questioning their current utilisation. At the core of this research endeavour is the necessity to assess the contribution of a particular system of utilisation of bio-resources in a given context to the natural, societal and economic development. Issues range from assessing the sustainable rate of extraction of harvest residues to the optimal form of re-integration of nutrients to retain or even improve fertility of land to the socio-economic impacts of complex bio-based “value networks” on local and regional population, to name just a few.

The more questioning existing utilisation pathways in the light of optimising the overall service of bio-resources leads to innovative utilisation patterns, the more acceptance by citizens on the ground becomes crucial. This issue ranges from the mundane, e.g. new ways to separate waste, to the multifaceted, e.g. the acceptance of new land-use patterns or innovative ways of governance regarding bio-resource utilisation. The sources for bio-resources cut to the heart of human well-being, either by impacting on eco-systems and landscapes or by changing everyday life routines. Any innovation therefore requires the consent of many stakeholders and knowledge about acceptance of change, taking natural, societal, psychological and economic context into account is crucial to success.

9.1.2 Non-technical research and innovation challenges with respect to bio-resource conversion

Advanced technology systems will be necessary to maximize the service potential of bio-resources. The non-technical innovation challenges concentrate on the so-called “innovation-paradox”, referring to the general problem in innovation that promising technological concepts don’t find their way to the market. This is an EU-wide problem for many economic sectors and one of the core arguments for developing the Lisbon strategy. The innovation paradox in bio-resources utilisation holds several intriguing non-technical innovation challenges. A first one is getting to know the effects of increasing diversity in bio-resource innovation processes. The bio-resource utilisation “value network” brings together knowledge and innovation traditions of different disciplinary and industrial backgrounds. According to innovation theory, diversity is important for innovation however it might complicate activities and results, since new partners have to learn to cooperate productively in new settings and under new circumstances. An intriguing question here is what the implication the diversity of actors has on innovation dynamics and innovation performance. A related question is what the differences and similarities are between innovation settings of different types of conversion technologies e.g. wood incineration, pyrolysis, torrefaction, bio refinery technologies. It is important to find out what the conditions are for productive innovation, what the barriers are and how to overcome them.

In this research it is important to account for the spatial context for two reasons. Bio-resource innovations are distributed unevenly between European regions. It is important to account for the local flavours to find out if and in what way they influence innovation dynamics and performance.

SMEs are major players in bio-resource convergence. Innovation routine in SMEs is however not similar to that in large industries that currently control important utilisation value chains, such as pulp & paper or sugar production. It is important to account for the diversity of SMEs located in the different regions in Europe to assess learning effects. The challenge in this respect is integrating the numerous SMEs into the knowledge innovation chain to make them solid part of innovation.

Regions and SMEs are also relevant and significant entrance points for research on diffusion patterns of bio-resource innovations. Relevant questions in this respect are how innovations diffuse into the market, how dominant technological designs are replaced by innovative, better performing designs and which factors in the selection environment influence the adoption of innovations.

Like in many other sectors that are subject to strong currents of innovation, bio-resource utilisation sectors face a development dichotomy: on the one hand there are vital and well developed industries with strong innovation capacities, which are striving to meet the challenges of a changing economic environment. On the other hand a variety of start-up companies riding a wave of innovative ideas and technologies. Both constituents of the innovation train however face different challenges. Whereas established companies command well managed engineering and sales capacities and have above all well optimised technologies and priority access to resource logistics, companies that are entering the market with new technologies at the beginning of the learning curve struggle with lower efficiencies, resource access and infra-structures that are not oriented towards their requirements. Research has to find ways how synergies between these innovation tracks can be harnessed and how both lines can converge towards the development of a strong and sustainable bio-economy in Europe.

9.1.3 Framing research on bottom-up drivers for the transition of regions to a bio-economy

Bottom-up innovation in the context of local communities has become an important driver, notably in energy innovation. Throughout Europe, local initiatives in neighbourhoods, villages, and cities have adopted the adage “think globally, act locally”. Numerous local and regional initiatives focusing on climate change/sustainable development have developed in the aftermath of the Rio conference. These bottom-up initiatives everywhere in Europe support the hypothesis that civil society and grassroots social movements in particular, are important carriers of sustainability transitions.

Part of the hypothesis is that local groups have the ability to develop innovative social practices which are influencing change in wider cultural norms. On the local level the initiative lies not only with the authorities but also with independent individuals and groups. It thus makes sense to focus on bottom-up innovation and transition dynamics initiated by local groups, associations and organisations, to get a better understanding of the drivers for the transition to a bio-economy, taking the spatial context into account. One of the intriguing questions in this respect is whether local initiatives have potential to change dominant energy practices in society. A related question refers to the drivers of the local initiatives. The hypotheses here refer to discontent with political problem solving, increasing societal complexity and the return to manageable span of control of problem solving, environmental concern, control over regional bio-resources and sustainable development, the focus on the benefits for the local economy. From an innovation perspective it is important to gain knowledge about these drivers as this will contribute to a better understanding of the change dynamics in society. This knowledge is important for developing supportive governance modes to accelerate the bio-economy transition in regions.

9.1.4 Innovation and knowledge diffusion for the transition of regions to a bio-economy

Schumpeter (1934) is generally considered as the intellectual origin of research on innovation and diffusion. He considered the entrepreneur to be the core actor in these processes. According to Schumpeter, entrepreneurs were individuals carrying through new combinations that would change an industry or the economy as a whole. The dynamics surrounding the initial and induced innovations would cluster in certain contexts and from there would spread to the rest of the economy.

Next to the Schumpeterian entrepreneur in the economic process, knowledge centers, education and policies are also carriers of knowledge diffusion. Additional to the economic oriented diffusion literature it is important to know more about the knowledge diffusion dynamics caused by universities, other knowledge centers and educational training programs. Do they indeed facilitate knowledge diffusion in Europe and if yes, in what way? What are barriers in this regard and how can knowledge diffusion from the have’s to the have not’s be improved?

Policy is another medium of knowledge diffusion. Here it is important to get a better understanding of the dynamics involved, the important policy arenas of knowledge diffusion. Like in the economic process, it is important to find out what makes a successful policy entrepreneur in diffusing innovative ideas across Europe.

9.2 Necessary technological research for the transition to a bio-economy

There exists a well-developed portfolio of technologies for the utilisation of bio-resources. Successful and well established industrial sectors like sugar industry, the forest based sector and pulp & paper as well as oleo-chemical industry have perfected their utilisation pathways based on primary bio-resources.

Besides these traditional bio-based sectors, a variety of technologies have been developed at an increasing pace over the last decades to utilise bio-resources in diverse ways. These technologies may be ordered for the sake of argument in this discourse book according to their role within the bio-resource utilisation chain:

- **Frontline Technologies**
  that process bio-resources with the predominant objective either to augment their logistic parameters or to condition them for the use in other technologies. These technologies have to be close to the land or source that provides the bio-resources in order to reduce transport burdens.

- **Grid-stabilising technologies**
  that may stabilise distribution grids, especially by providing grid-overarching energy services and/or storable energy carriers.
- **Gateway technologies**
  that up-grade bio-resources, usually products coming from frontline technologies, to sophisticated and complex products
- **Rear-guard technologies**
  that utilise low grade bio-resources and wastes (tertiary bio-resources) and condition material flows so that they can be safely integrated into the ecosphere.

Table 8 provides examples of the most commonly used bio-resource based technologies and indicates their role according to this classification.

Table 8: Examples of existing technologies for bio-resource utilisation

Type of technology	Technology	Resources	Products	By-products	Size	Remarks
Conditioning	Pelletizing, pressing, shredding, steam explosion, …	All primary & secondary bio-resources	Intermediate products for further processing	none	Very small to medium	Frontline technology
Extractive technologies	Steam distillation, extraction, pulping, …	All primary & selected secondary bio-resources	Valuable ingredients	Secondary bio-resources	Small to industrial	Frontline technology
Thermal treatment	Combustion	Dry primary & secondary bio-resources	heat	Ashes (high transport densities, nutrient rich)	Very small to industrial	Rear-guard technology
	Combined heat and power (CHP)	Combustion heat	Lower grade heat and power	none	Very small to industrial	Potential grid stabilisation technology
	Pyrolysis	Dry primary & secondary bio-resources	Low grade gas, pyrolysis oil, char coal	Ashes	Small to industrial	Frontline technology
	Gasification/ Fischer Tropsch Synthesis	Dry primary & secondary bio-resources	Hydrocarbons	Ashes	Industrial	Gateway technology
Biotechn. technologies	Submerged bio-conversion	Bio-resource derived substrates	All organic compounds	Liquid/wet secondary bio-resources	Industrial (due to downstream processing)	Gateway technology
	Solid state bio-conversion	humid primary & secondary bio-resources	Intermediate products	Humid secondary bio-resources	Very small to medium	Front line technology
	Anaerobic digestion	Humid/ liquid bio-resources	Biogas	Liquid, low solid fraction manure	Small to medium (industrial)	Rear-guard technology, flexible grid stabilisation

Development Challenge:

The innovation challenge for these conventional technologies will be to increase their flexibility with regard to the resources they may utilise as well as the products they generate. Developing technologies that are robust enough to cope with lower grade (secondary and tertiary) resources, multi-feed and mixed-feed technologies as well as expanding the range of properties of products from these technologies will be required for a successful transition to a bio-economy.

The key technology elements described above will have to be combined in a systemic way to provide the services we expect from bio-resources efficiently in a given context. These technology combinations constitute *bio-refineries*. The term was first coined by Carlsson (1983) in connection with a systemic way to utilise green biomass. Since then it became the catch word for networks of technologies that utilise a given supply portfolio of bio-resources fully. This means that a bio-refinery system produces material goods, energy services and by-products that are re-integrated into the ecosphere but no wastes, drawing optimal service from a full life cycle of bio-resources.

Development Challenge:

Efficient utilisation systems for bio-resources have to be adapted to context. This pertains to the natural endowment, existing infrastructure as well as to the economic and social framework. That entails the development of tools to generate complex technology networks that may be spread out at different locations, with de-central frontline technologies close to fields and forests, central industrial size gateway technologies and rear-guard, grid-stabilising technologies at intersections of distribution grids, situated to optimise the logistics of resource provision and by-product re-integration into the ecosphere. The innovation challenge is not only to develop such complex systems, but to adapt them to their regional context.

As bio-resource based technology systems become increasingly complex and as the have to cope with complex raw materials with a particularly wide margin of quality, the pilot-scale step within the technology development path becomes ever more important. This step however is costly while it still has considerable development risk. It is therefore important to increase co-operation across Europe to support stakeholders to overcome this crucial innovation step.

Development Challenge:

Pilot-plant centres for technologies based on bio-resources must be created and new forms of innovation co-operation developed that allow stakeholders along the technology development path to effectively convert ideas to industrial processes as well as to optimise complex technology systems with moderate cost and bearable development risk.

9.3 Establishing an analysis and evaluation system for the transition of regions to a bio-economy

Given the complex technological possibilities and logistical considerations establishing an optimal technology system that takes into account the spatial context is no longer intuitive but often requires the help of planning instruments24. In many cases the discourse within a region about its bio-resource utilization will inevitably lead to different scenarios that must then be analyzed and evaluated. This requires comprehensive evaluation tools for sustainability and land-use.

FAO25 reviews the available tools for environmental and socio-economic dimensions. The tools are classified according to their functionalities on specific categories and planning and monitoring capabilities. Applicability of the tools is discussed at the regional, local or farm levels, neglecting the supply chain level.

The research for developing an efficient evaluation system for the transition of regions to bio-economy must be based on a holistic supply-chain approach. This is particularly crucial to address the individual needs of the stakeholders involved in bio-resource supply chains (BRSC) and to measure the whole chain performance from economic, environmental, and social perspectives. Obviously bio-resources can be used in different regions from their origin, requiring inter/multi-regional planning at national level. Therefore, the evaluation tool should measure sustainability at two levels to address the operations of companies and the associated impacts on the relevant stakeholders: (i) supply chain level and (ii) regional level.

Adoption of new strategies to implement bio-based economy requires the involvement and integration of several stakeholders at the regional level. The basis of such integration is the cooperation between the supply chain actors. While the environmental and social sustainability of bio-resource use are strongly affected by the operational performance of BRSC, the decisions-to-cooperate of supply-chain members are driven by profitability. This implies the economic satisfaction of the actors of bio-resource supply-chains, including (potential) suppliers, biomass processors, by-product evaluators, final product retailers, third party logistics players, process integrators (e.g. bio-refineries) and final consumers. On the other hand, the major interest of regional and national governments and the society are mostly related to the social and environmental performance of the bio-resource utilisation, e.g. employment, effects of land-use, regional wealth.

Developing a comprehensive and coherent framework to analyse and assess these different aspects of bio-resource utilisation is a necessity to support successful implementation of a bio-economy. Therefore, independently from their structure, the evaluation tools for the regional transition must be able to measure a series of economic, environmental, and social sustainability indicators in a comparative manner not only at whole supply-chain level but also at individual actor level.

[24] See e.g. RegiOpt software available from www.fussabdrucksrechner.at [February, 2014])
[25] A compilation of tools and methodologies to assess the sustainability of modern bioenergy (FAO, 2012) accessible from http://www.fao.org/docrep/015/i2598e/i2598e00.htm

10 How to use bio-resources rationally

10.1 General imperative resulting from the nature of bio-resources

There is one particular aspect of the nature of bio-resources that has to be taken into account when utilising these resources: their "limited infinity" nature, meaning that they are limited in terms of their flow (e.g. their yield per hectare and year), but this flow will be infinitely available if the basic ecological resource, in particular land, is managed sustainably. This gives raise to the following general framework.

10.1.1 Do not waste – use effectively

As a limited but crucial basis for human survival and development, bio-resources require the highest possible efficiency of conversion into services. Wasted bio-resources mean that limited natural income has been squandered.

There are two aspects to this imperative. The first is linked to the limiting factor of land as a production factor for bio-resources. Natural income is only then fully utilised if everything that land can sustainably produce is converted into a service to society and/or the environment. Off-spec parts of crops and low quality harvest residues will not be taken up in the food value chain. Integrated technology systems are able to process these resources as far as they are not needed to preserve fertility of the land and provide energy services or commodity products.

The other aspect of this rule concerns the efficiency of the value chain based on bio-resources. Wasting crops, by-products or intermediate products along the life cycle of bio-resources from generation to end use or, even worse, wasting the end product itself clearly violates rational use of a strictly limited resource.

10.1.2 Life-cycle wide responsibility for bio-resources

The conversion of natural income to bio-resources needs other production factors, the most prominent among them fertile land on which this conversion takes place. In addition the conversion requires material building blocks like water, CO_2 and nutrients. Retaining the fertility of the land means that human utilisation of bio-resources has to latch into global material cycles for water, carbon and nitrogen and replace those nutrients that do not form natural cycles, such as minerals.

The moment a (primary) bio-resource is harvested, responsibility for this material is transferred to human society. This means that any use of bio-resources requires the management of the material life cycle starting with the harvest and ending with the re-integration of all residues after human use. In practical terms this management must take care of bringing back nutrients to the land in quantities and qualities which guarantee that land fertility is retained.

10.2 Define the context for sustainable bio-resource utilisation

Bio-resources are contextual resources. The generation of primary resources is dependent on a concrete ecosystem. Demand for resources as well as the generation of secondary resources is shaped by socio-economic context. The decision how to sustainably balance the use of bio-resources is therefore only possible if the context is taken into account. Therefore recommendations that guide such decisions have to be context related.

10.2.1 Defining the spatial context

The utilisation of bio-resources is based on societal decisions made in a concrete spatial context. Setting the spatial context therefore implies a complex interplay between society and its spatial context. It is however a social decision as it involves the interaction between various actors, their social and political relation and their identities (Berger, 2004). Regions are after all not lines on a map but cognitive concepts relating society to space. Any rational approach to utilising bio-resources must therefore start with a thorough discourse about delimiting the spatial context, thus defining a region that will form the framework for handling bio-resources. It is also necessary to define the development visions for the region in question in this social discourse.

10.2.2 Defining the environmental framework

The natural endowment of a region in the form of fertile land, functioning water systems and bio-diversity is the capital from which the natural income in the form of bio-resources can be generated. This capital must not decrease over time. On the contrary, regions should strive to improve their ecological functions in order to increase this natural capital. This requires however setting aside part of the land and/or limiting the intensity of appropriation of bio-resources or structuring land use in order to fulfil the environmental services of preserving natural material cycles, bio-diversity and soil fertility in the long run.

10.2.3 Defining the social framework

Every region has to fulfil social and economic functions within environmental limitations. With regard to bio-resources the most important aspect is the responsibility to provide the service of nutrition. This responsibility is of course dependent on the natural endowment of the region. Realisation of this responsibility must however be guided by the general rules for the utilisation of bio-resources, in particular the rule to use bio-resources fully. This implies that the responsibility to provide food must be based not only on the natural endowment of the region but also on an efficient supply chain from the region to the consumers of food, avoiding any waste along the distribution paths.

The land necessary to provide food to meet the nutrition responsibility may not be used to provide primary bio-resources to cover other services defined in Table 7. Residues from providing food, either direct harvest residues or by-products of from processing food may however be used for the provision of any economic service listed in this table, as long as no environmental service is put in jeopardy.

10.3 Develop sustainable regional bio-resource utilisation systems

Besides preserving or even improving ecological performance of land and providing nutrition, bio-resources are the foundation for creation of sustainable jobs and wealth in rural regions. These are services that may also not be provided by other resources and must therefore be given priority within the framework established by the fulfilment of ecological services and the provision of food, before fulfilling other requests to bio-resources.

There is no general rule for providing these services. The pathway towards achieving the goal of sustainable regional development is dependent on a range of contextual parameters such as the existing economic structure e.g. the existence of conventional sectors of bio-resource utilisation, the existence of markets for particular products and services as well as education and qualification levels in the region, to name the most prominent.

10.3.1 "Refinerize" conventional sectors

Bio-resources are the only possible basis for sectors that conventionally utilise wood and crops such as pulp & paper, timber or oils & fats industry but also the food sector. These sectors provide products that cannot easily be replaced by other goods or services and render decent profits along their value chain. Moreover such industries have established well organised logistical systems and provide jobs and income as well as skills and qualification for employees. Putting priority to serving these sectors is sensible and in the case of the food sector even obligatory.

The sectors themselves however have to evolve into flexible bio-refinery systems based on their main resource but accommodating other (secondary) bio-resources provided by their spatial and economic context.

A marked difference between fossil-oil refineries and this new type of bio-refineries lies in their resource range: whereas oil refineries typically utilise only crude oil these bio-refineries will have to accommodate intermediate products from secondary bio-resources. Using frontline technologies de-centrally to improve their logistic properties and their quality, these intermediate products (straw pellets, pyrolysis oil, etc.) may be processed in large scale bio-refineries to increase the resource base for ancillary processes, improving economy of scale of these processes and jointly utilising distribution channels for final products.

10.3.2 Give priority to material goods

Bio-resources are a convenient pathway to convert natural income of solar radiation into material goods. Fossil resources are currently strong competitors for the provision of synthetic materials and fuels. In the long run however bio-based technologies will supply a major fraction of material goods for daily and short-term consumption.

Material goods provide higher added value on the resource than energy services as they offer opportunities for longer and more complex value chains. Their provision therefore will bolster the economic viability of a bio-economy.

The optimal utilisation network for the bio-resources is subject to an in-depth systemic planning process. Some hints may however be useful in this respect:

- Any high quality primary field-crop grown within the framework of providing ecological services to the region that is neither required for meeting the nutritional responsibilities nor taken up by conventional sector based bio-refineries may be provided to the production of high value material goods (pharmaceuticals, special chemicals, etc.)
- Non-food primary bio-resources of lower grade and with less advantageous logistic parameters (wood, grass, etc.) as well as harvest residues grown within the framework of providing ecological services to the region and not taken up by conventional sector based bio-refineries may be converted to platform intermediate products for further treatment. These platform products range from simple pellets to chemicals like lactic acid or alcohols to

pyrolysis oil and char coal to longer chain hydrocarbons from Fisher-Tropsch Synthesis. The choice which line(s) to pursue depends on the context, e.g. the existence of conventional sector based bio-refineries that can accommodate these resources, technological potential of the regional economy, qualification of the workforce and distance to possible sites of up-grading intermediate products.

10.3.3 Retain as much material as possible close to productive land

Preserving the productivity of the primary resource land is to a large extent depending on closing material cycles and returning nutrients to the land. This requires that any part of bio-resources that is not converted into material goods (be they nutritional or for other purposes) shall be recycled to fields, grass land and forests. As most of the waste flows generated by the utilisation of bio-resources have particularly unfavourable logistic parameters their transport distances must be kept short. This demands that frontline as well as rear guard technologies as defined in Table 8 shall preferably be realized de-centrally, close to the origin of bio-resources.

10.3.4 Use intersections of distribution grids as a means to fully utilise bio-resources

Biogas production and combustion are typical technologies that should be based on low grade bio-resources. These technologies have a narrow product portfolio: combustion provides heat, combined heat and power (CHP) and biogas can be up-graded to bio-methane or used in a CHP to generate heat and power. All these products may be distributed via distribution grids. The optimum location for these technologies therefore is where these grids intersect.

Bio-resources are however much too valuable to be converted to heat only or base-load electricity. The service they may provide with advantage is stability of distribution grids, in particular electricity grids. This means that de-central bio-resource based energy technologies shall always include (CHP) units and that these units shall be operated according to the needs of electricity grid stability if technically feasible, storing the heat when heat demand and electricity demand diverge.

Particularly advantageous are trivalent technologies. These are technologies that produce bio-methane either from anaerobic digestion in combination with gas cleaning or from biomass gasification with catalytic conversion to synthetic natural gas. These technologies can serve all energy distribution grids, from heat to electricity to gas. These technologies should also be operated according to the electricity grid requirements, switching to gas production and storage of gas in the gas grid whenever no electricity is necessary to stabilise the grid and serve heat customers via heat storage systems.

The necessary proximity of heat users to thermal bio-energy providers gives raise to another type of bio-refinery: de-central bio-refineries converting secondary or under-utilised bio-resources to intermediate “platform” materials, improving quality and transport properties and conditioning these bio-resources for processing in central large scale bio-refineries.

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