HOOU online ‘lectures for future’ series

“Bioresource Management”

Section: Residue and by-product based bioresources

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Online lecture version:

https://www.hoou.de/projects/lff/pages/residue-and-by-product-based-bioresources

Printable Lecture Version

Bioresource Categories:

Primary, Secondary, Tertiary and Quaternary Bioresources

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Slides from the online lecture

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Bioresource Categories: Primary, Secondary, Tertiary and Quaternary Bioresources

Ina Körner

Part 1: Bioresource Categories

Residue and by-Product Based Bioresources

Introduction (0:59 min.)

Lecture Parts

Part 1: Introductory Lectures on Biorefineries and Bioresources

Lecture "Bioresource Categories"

- Bioresource Basics
- Categorisation Approaches
- Primary, Secondary, Tertiary and Quaternary Bioresources
- Examples for Bioresources and Their Transformations
- Conclusion

Lectures Overview

Part 2: Main Lectures on Bioprocesses and Bioresource Chains
Part 3: Case Study Lectures on Interdisciplinary Projects
Part 4: Lectures on Support of Sustainability by Bioresource Uses

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Part 1: Bioresource Categories | Media

What Is a Bioresource?

Definition



Bioresources are non-fossil biogenic substances, which can be used by humans for the following purposes:

The production of food, feed, substantial products or energetic products.

They can be specifically grown for such purpose as primary bioresources or are generated as by-product or residue, for instance during a processing or consumption activity.

(updated from Körner 2015)

***Video**: Bioresources and Bioresource Chain Management*

***Master Studies**: Wood Science (in English)*

***Bachelor Studies**: Bioressourcen-Nutzung (in German)*

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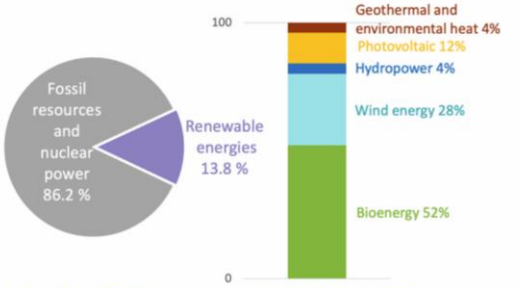
Bioresources as Fossil Resource Substitutes

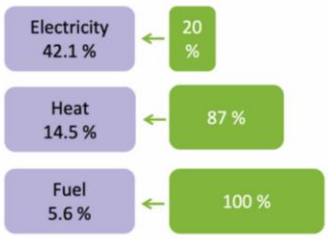
Bioenergy



Renewable Energy Share, Germany 2018 in % of End Energy Consumption, Based on Data from BMWi (2019, p.9)

Renewable Energy Types, Germany 2019 in % of Total Renewable Energy Provision, Based on Data from UBA (2020)

Bioenergy Share within the Sector, Germany 2019 In % of the Sectorial Renewable Energy Provision, Based on Data from UBA (2020)



Renewable Energy in Main Providing Sectors, Germany 2019 in % of Total Sectorial Energy Provision, Based on Data from UBA (2020)

Which Products Are Bio-Based Products?

- *Garbage Collection Bag A*
- *Garbage Collection Bag B*
- *Collection Bag for Dog Excrements A*
- *Collection Bag for Dog Excrements B*

Detailed references and image licences can be found at the end of the lecture in slides 17-21.

Main Components in Bioresources

Bioresource group	Important organic compounds
Plants	• carbohydrates (saccharides) • proteins • fats, oils, fat containing molecules • lignin and other aromates
Algae	• carbohydrates (saccharides) • proteins • fats
Animals	• proteins • fats, oils, fat containing molecules
Microorganisms and fungi	• chitin / murein • proteins and protein containing molecules • nucleotide and nucleic acids
Animal and human excrements	• urea • incompletely digested feed / food with remains of the previous mentioned compounds

Primary bioresources are composed of organic and inorganic compounds as well as water. Different types of organic compounds are generated naturally during growth of the organisms. During use, they may be transformed.

Although bioresources are manifold, the organic compounds can be basically broken down into four classes, which make up the bulk of the organic components:

Carbohydrates | Lipids | Proteins | Aromates

Schematic Composition of Various Bioresource Types (Redrawn from Saake 2004)

Databases with Specific Bioresource Composition Data

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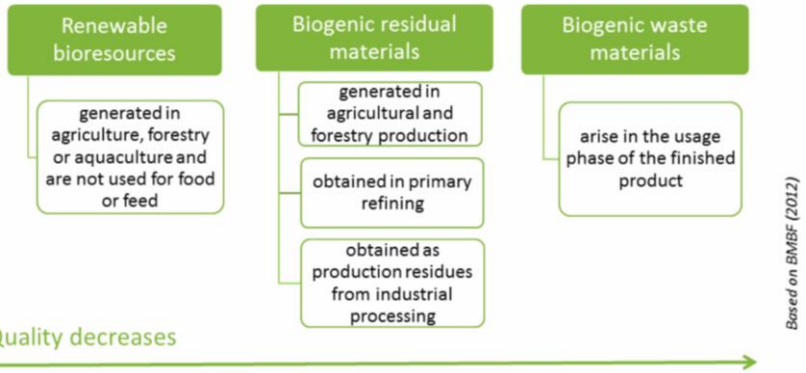
Bioresource Categories for Biorefineries

Categorisation by the German Ministry of Education and Research



Based on BMBF (2012)

Multiple Forms of Categorisation (1:56 min.)

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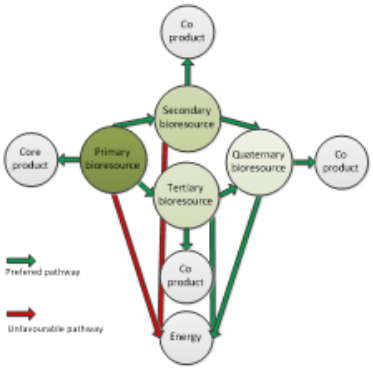
Part 1: Bioresource Categories

Advanced Bioresource Categorisation

Considering Origin, Properties and Application Suggestions



- A bioresource can be used multibranched – to produce one core product and several co-products.
- After food consumption or after substantial utilisation of a bio-based product, some of the components may be used again for making a recycling product (re-product). In this way bioresources can be used in cascades.
- The final stage is energetic utilisation (or disposal).

Multibranch and cascade utilisation of bioresources connected with a final energetic utilisation step are key aspects towards efficient bioresource utilisation and ecological sustainability (Körner 2015).

Part 1: Bioresource Categories **Important**

Primary Bioresources

Virgin primary bioresources
Cultured plants, animals, algae, microorganisms, fungi, insects

Processed primary bioresources
Materials

Consumer products



Shares remaining on-site

Secondary and tertiary bioresources

The whole non-processed culture is the starting point of processing. During primary processing one core product is generated, which is transformed by further industrial processes into consumer products. During processing, shares of the virgin bioresource are separated.

Part 1: Bioresource Categories **Attention**

Primary Bioresources

Production Areas: Forestry, Agriculture, Aquaculture



They are produced for a specific use-oriented purpose. They should be used to make food, feed or substantial products. It is not recommended to use them for energy production.

Not all plants or animals can be considered as a primary bioresource.

Examples:

plants from parks and gardens → *have a recreational function*

primeval forest plants, wild living animals → *are not grown for a use-oriented purpose*

pet animals → *have as function to accompany humans*

(Körner 2015)

Secondary Bioresources

General characteristics:

- occur in large quantities
- have low content of impurities
- are preferred for higher value applications

Examples: Wood Chips in Sawmills

Lawn Cuttings in Golf Courses

Generated in two principal sectors:

Processing by-products or residues from primary or further industrial activities from primary virgin or processed bioresources.

Maintenance residues of large areas (e.g. parks, lawns, sport places, dikes) if harvested as pure fraction in large amounts.

Tertiary Bioresources

General characteristics:

- Small amounts occur at generation place
- Many generation places exist
- Composition may be hard to define
- Impurities may be contained
- Do not result from a consumed product

Generation sectors:

Processing and retail sector: As waste at commercial level during harvesting, post-harvesting, primary processing and storage, industrial processing, packaging, retailing.

Consumption sector: As preparation waste or wasted product at consumer level in small businesses (e.g. in restaurants, canteens) and in private households (e.g. in kitchens).

Maintenance sector: As waste (e.g. tree prunings, lawn cuttings, autumn foliage) at private and commercial level during care of gardens and other green areas.

Quaternary Bioresources

Short term

Generated directly after or with short delay after consumption in a time scale of minutes to hours (e.g. excrements after food or feed consumption).

Mid term

Generated in days to months after begin of utilisation (e.g. packaging materials, newsprints).

Long term

Generated years after begin of use (e.g. wood construction materials, furniture).

General Characteristics:

- Occur after a product was consumed
- Composition may be hard to define
- Impurities may be contained

Examples for Assignments of Bioresources to the Different Categories

PRIMARY SECTOR	Primary Bioresource	Secondary Bioresource	Tertiary Bioresource	Quaternary Bioresource
AGRICULTURE	Wheat	Wheat husks	Waste bread	Human excrements
AGRICULTURE	Orange tree	Orange peels in food industry	Orange peels in households	Human excrements
AGRICULTURE	Pig	Bones in slaughterhouse	Spoilt pork chops in households	Bones from eaten pig chops
FORESTRY	Spruce	Bark	Unused paper thrown away in households	Wastepaper
LANDSCAPING	-	Prunings from roadside trees	Green waste from private gardens	Dike sheep excrements

They should be avoided as first priority, but if they occur, they should be utilised.

Examples for Biogenic Raw Materials, Residues, Wastes, and Wastewaters Generated in Various Sectors and Their Assignment to a Bioresource Category (Körner 2015, p.303)

Multiple Choice Questions

Drag and Drop Exercise

Detailed references and image licences can be found at the end of the lecture in slides 17-19.

Comparison of Properties and Suggested Products from Bioresources of the Different Categories

PROPERTY	Primary Bioresource	Secondary Bioresource	Tertiary Bioresource	Quaternary Bioresource
ORIGIN	Grown in agriculture, forestry, aquaculture	Industrial processing or maintenance sector	Processing, retail, waste and wastewater management, maintenance sectors	Waste and wastewater management
USAGE TYPE	primary	multi-branch	multi-branch	cascade
PRODUCT TYPE				
Food	x	x	–	–
Feed	x	x	x	–
Substantial product	x	x	x	x
Energetic product	–	(–)	x	x

Detailed references and image licences can be found at the end of the lecture in slides 17-21.

Example for the Transformation of Bioresources

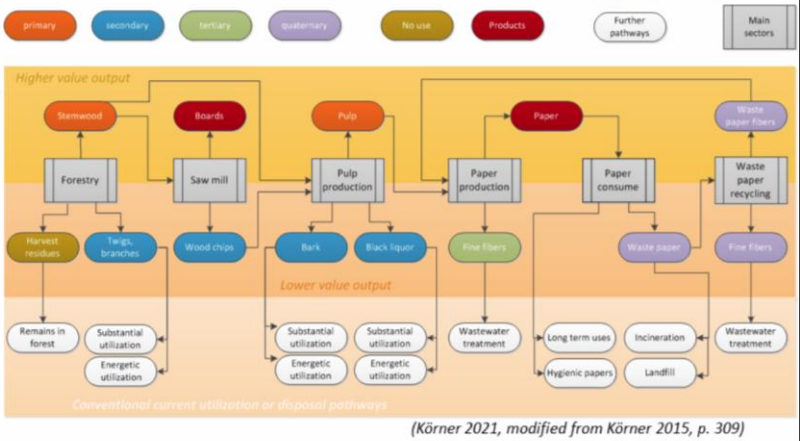
The Paper Chain (3:23 min.)

The Paper Chain

Note:
The presented chain from forestry to wastepaper recycling is simplified.

Wastepaper fibres can be reused. In that case, they enter the chain again at the "Paper production" stage resulting in a cascade utilisation.

Most lower value outputs of the various process stages are substantially or energetically used, contributing to a multichain utilisation.



(Körner 2021, modified from Körner 2015, p. 309)

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Conclusion

- Low-value bioresources should be used for the production of mass products, high-quality ones preferably for high-quality products.
- Cascade use of bioresources is usually possible, if end-of-life products or other quaternary bioresources are available in large quantities and suitable purity.
- If a substantial use is not possible under reasonable conditions, the bioresources should be used to make energy, thus ending the chain.
- The categorisation of bioresources into primary, secondary, tertiary and quaternary bioresources helps to design efficient utilisation pathways.
- Categorisation may help to avoid an inefficient bioresource use and to prevent the use of a high-quality bioresource for the production of a low-value product.
- A bioresource use contributes to many of the Sustainable Development Goals (SDGs).

Bioresource use contributes among others to following SDGs (UN 2020):

Detailed references and image licences can be found at the end of the lecture in slides 17-21.

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Slide 4 (right): Renewable Energy in Main Providing Sectors and Bioenergy Share within the Sector, Germany 2019 in % of Total Sectorial Energy Provision by Ina Körner <https://www.hoou.de/projects/lff/pages/residue-and-by-product-based-bioresources> is licensed under CC BY-SA 4.0: <https://creativecommons.org/licenses/by-sa/4.0/>. This image was based on data from UBA (2020).

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Slide 4 (quiz): Garbage Collection Bag A, Garbage Collection Bag B, Collection Bag for Dog Excrements A & Collection Bag for Dog Excrements B by Ina Körner <https://www.hoou.de/projects/lff/pages/residue-and-by-product-based-bioresources> are licensed under CC BY-SA 4.0: <https://creativecommons.org/licenses/by-sa/4.0/>.

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Slide 9 (right): Gartenmöbel by Nennieinszweidrei <https://pixabay.com/de/photos/gartenm%C3%B6bel-holzm%C3%B6bel-stuhl-4397207/> is free for commercial and non-commercial use.

Slide 10 (left): Sägewerk by Denis-Triton <https://pixabay.com/de/photos/flucht-gleitschirm-s%C3%A4gewerk-h%C3%B6he-2259702/> is free for commercial and non-commercial use.

Slide 10 (right): Golf Course by 70154 <https://pixabay.com/photos/golf-course-golf-golfing-manicured-203223/> is free for commercial and non-commercial use.

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Slide 11: Large Amounts of Biowaste by Collection of Small Amounts from Multiple Sources by Ina Körner <https://www.hoou.de/projects/lff/pages/residue-and-by-product-based-bioresources> is licensed under CC BY-SA 4.0: <https://creativecommons.org/licenses/by-sa/4.0/>.

Slide 15: The Paper Chain with Assignments of the Involved Bioresource Fractions to the Classes Primary, Secondary, Tertiary and Quaternary Bioresources by Ina Körner <https://www.hoou.de/projects/lff/pages/residue-and-by-product-based-bioresources> is licensed under CC BY-SA 4.0: <https://creativecommons.org/licenses/by-sa/4.0/>. This image is based on Körner (2015).

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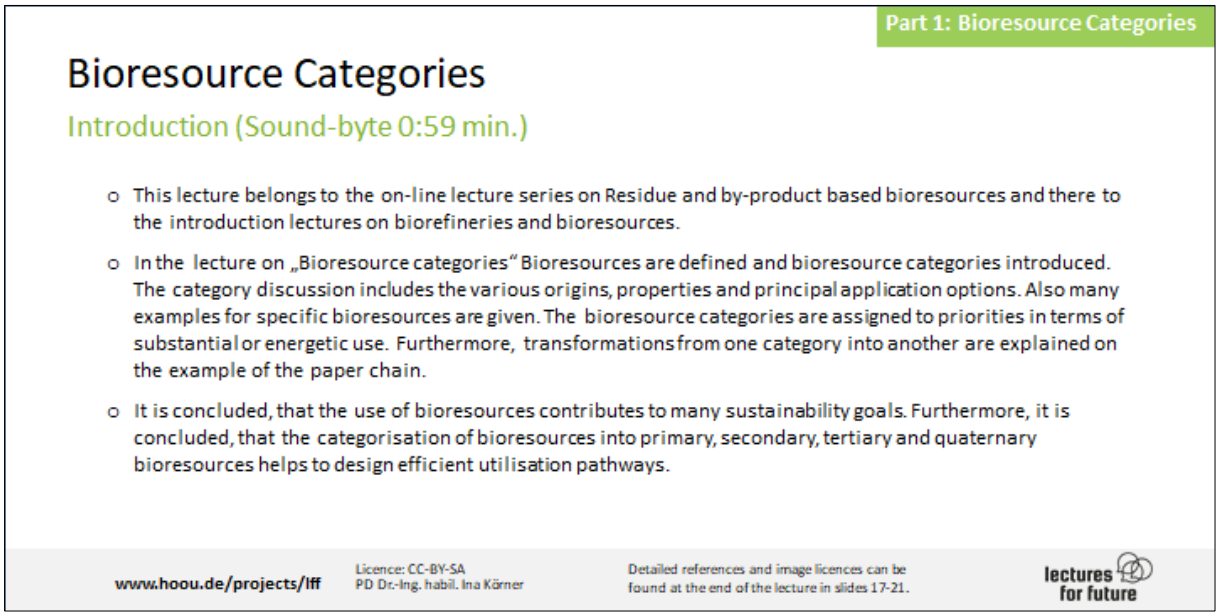
B.

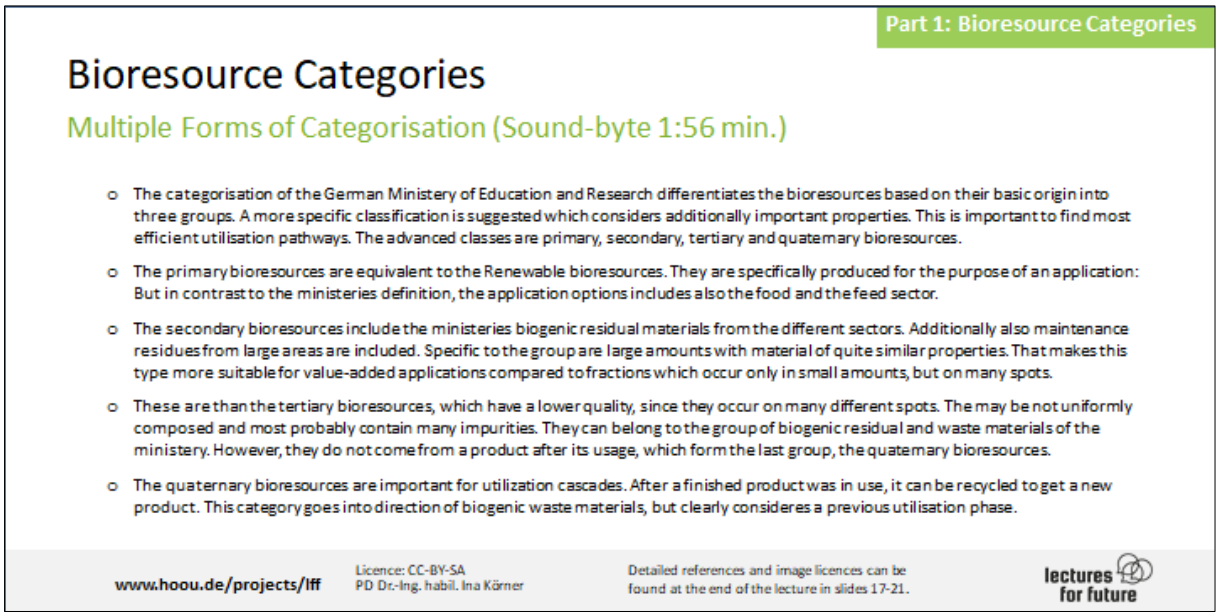
Add-ons from the slides

B1. Scripts from voice parts

Audio (Page 1/Slide 2)



Audio (Page 2/Slide 6)



Audio **(Page 5/Slide 15)**

Part 1: Bioresource Categories

Bioresource Categories

The Paper Chain (Sound-byte 3:23 min.)

- On the example of the paper chain, I want to explain the interrelations between primary, secondary, tertiary, and quaternary bioresources. The complex processes within the chain are simplified for that purpose.
- The paper chain starts in the forest. A spruce tree, for instance, may be harvested about 100 years after planting. Stemwood is the core output. It is the primary bioresource considered for further processing. Rootes and partly twigs and branches remain in the forest and contribute to soil improvement. These harvest residues are not considered as bioresource for further use.
- From forest to pulp mill secondary bioresources are generated such as low quality wood chips and bark. These can be used for instance for energy generation. For that purpose, a part of the twigs and branches can be shredded to make the chips. Bark is removed in the pulp mill, since it would lead to dark spots in paper.
- Stemwood not always goes to pulp production. It can also be used in a sawmill for making timber. The lower quality parts from the log are also a secondary bioresource. They can be shredded to wood chips and delivered to pulp production.
- For pulp production debarked stemwood is hackled to wood chips. The wood chips than are treated thermo-chemically and mechanically. The main output is the pulp consisting of virgin cellulose fibers. The by-product is black liquor which contains lignin and hemicelluloses. It is a secondary bioresource, which is currently often used energetically. But the black liquor has also a high potential for substantial use.
- To make paper, fibers and other inputs are mixed with water. Virgin cellulose fibers from pulp mills are primary bioresources. Fibers from recycled paper are quaternary bioresources. Besides fibers, non bio-biobased mineralic compounds are used. In the paper machine, the fiber-containing suspension is distributed onto a mesh, water is removed and the paper web is rolled. During mechanical dewatering a small amount of fiber fines are discharged and treated.
- The paper consumption is the core of the chain. When the consumer does not need the paper product anymore, it becomes wastepaper, which is than a quaternary bioresource. Wastepapers from newsprints, books, and packaging materials can be collected and recycled. However, some of the paper products cannot be recovered such as toilet papers which are disposed in toilets. Around 20% of wastepaper is not available for recycling.
- During wastepaper recycling the wastepaper fibers are recovered. Fibers are separated from other paper ingredients such as ink, pigments and filling materials. However, during recycling fibers may get shorter due to mechanical stress. Currently a fiber is used about 6 to 8 times till it is to short.
- Since fine fibers are not usable for paper production they are removed. They accumulate in the deinking sludge together with other paper ingredients. Deinking sludges are treated with a part ending in wastewater treatment, and a other currently often in incineration for disposal. But deinking sludges have also a potential to make bioenergy and to use the mineralic sludge compounds in the construction industry.

B2. List of links

Page 1/Slide 2: Lectures overview: http://www.bioresource-tools.net/files/lff_overview_2021.pdf

Page 7/Slide 17: References database: https://www.zotero.org/groups/2496968/lectures_for_future/collections/HWSTZ8SE

B3. List of images and videos

Image (Page 2/Slide 4)

Figure 1. (Left to Right): Garbage Collection Bag A, Garbage Collection Bag B, Collection Bag for Dog Excrements A, Collection Bag for Dog Excrements B

Image (Page 2/Slide 5)

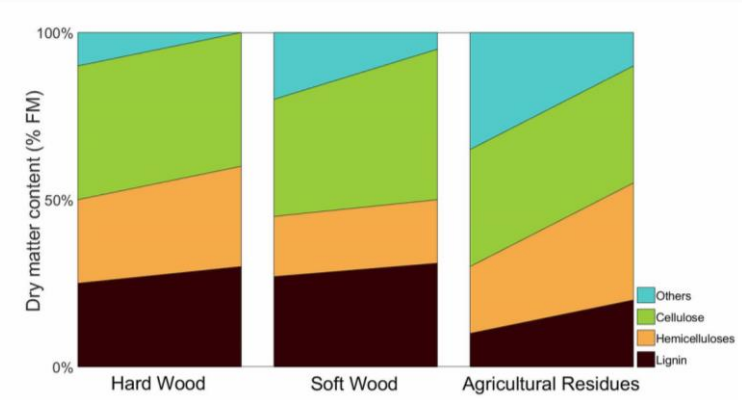


Figure 2. Schematic Composition of Various Bioresource Types (Redrawn from Saake 2004)

B4. Content of info boxes

Info **Page 2/Slide 4**

Info: Bio-based products are defined in the German standard DIN EN 16575 as follows:

“Der Begriff biobasiert bedeutet von Biomasse abgeleitet. Biobasierte Produkte (Flaschen, Dämmwerkstoffe, Holz und Holzprodukte, Papier, Lösemittel, chemische Zwischenprodukte, Verbundwerkstoffe, usw.) sind Produkte, die vollständig oder teilweise von Biomasse abgeleitet sind. Von erheblicher Bedeutung ist es, die Menge der im Produkt enthaltenen Biomasse zu charakterisieren, zum Beispiel den biobasierten Gehalt oder den Gehalt an biobasiertem Kohlenstoff.” (DIN EN 16575:2014-10)

“The term bio-based means derived from biomass. Bio-based products (bottles, insulation materials, wood and wood products, paper, solvents, chemical intermediates, composites, etc.) are products that are wholly or partially derived from biomass. It is of considerable importance to characterise the amount of biomass contained in the product, for example, the bio-based content or the bio-based carbon content.” (translated from DIN EN 16575:2014-10)

Video: Bioresources and Bioresource Chain Management:

https://www.youtube.com/watch?v=SXHhW4qkBDs

Master Studies: Wood Science (in English):

https://www.biologie.uni-hamburg.de/en/forschung/oekologie-biologische-ressourcen/holzchem/lehre/msc-wood-science.html#Mehr%20erfahren#Mehr%20erfahren

Bachelor Studies: Bioressourcen-Nutzung (in German):

https://www.biologie.uni-hamburg.de/forschung/oekologie-biologische-ressourcen/holzchem/lehre/bsc-bioressourcen-nutzung.html#Mehr%20erfahren

Info **Page 2/Slide 5**

Note: Within a group, and also for different representatives of one bioresource species, variations in the specific composition may occur. The variations within a group are shown in the figure in trend. They are in tendency larger for agricultural residues compared to wood. Source: Saake, B 2004, Personal provision. Hamburg University, Institute of Wood Science, Wood Chemistry.

https://www.biologie.uni-hamburg.de/en/forschung/oekologie-biologische-ressourcen/holzchem/personen/mitarbeiter/saake.html

Databases with Specific Bioresource Composition Data: "Phyllis is a database containing information on the composition of biomass, macro- and micro-algae, feedstocks for biogas production, biochar and torrefied biomass. Phyllis provides data for individual materials or average values for a group of materials." "The CIRAD wood chemical composition database is a part of the general CIRAD wood database […]. 614 wood species are described with measurements of wood polymers (cellulose, lignin and pentosan) and overall extraneous components (ethanol-benzene, hot water extracts, ash, silica content)."

B5. Questions and exercises with answers

Questions (Slide 4/Page 2) *(See page 17 for answers)*

Question 1: *Garbage Collection Bag A*

Information from the garbage bag: Company: DEISS; Product name: Bioline; Fully compostable; Renewable raw materials > 50%; DIN certified: bio-based 50-85%; Basic material: Ecovio from BASF, certified compostability, mostly bio-base

Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Question 2: *Garbage Collection Bag B*

Information from the garbage bag: Product name: PRIVA; Volume: 15 L; Compostable (7P07135)

2a) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Information from webpage A: Material: Bioplastic-foil from "MaterBi" Type CF 06

2b) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Information from webpage B: Certificates for MaterBi: Contains renewable raw materials, Biodegradable, Compostable ISO 13432 (manufacturer), Compostable ISO 13432 (certificate)

2c) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Question 3: *Collection Bag for Dog Excrements A*

Collection Bag for Dog Excrements A

Information from the bag: Company: Brosch-pe; Product name: Dog-Bag

3a) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Collection Bag for Dog Excrements A

Information from a webpage: Material: 1A material or 100% regenerate; Certified climate neutral company: climatpartner.com 15689-2002-1001

3b) Based on this information, which among the following is true for this bag

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Collection Bag for Dog Excrements A

Contacting the company: Made from 1A material: HDPE

3c) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Question 4: *Collection Bag for Dog Excrements B*

Collection Bag for Dog Excrements B

Information from the bag: The environmentally compatible dog excrement bag.

4a) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Collection Bag for Dog Excrements B

Information from a webpage: Name of a providing company

4b) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Collection Bag for Dog Excrements B

Information from the company: Data sheet for green, red and black bags with information regarding dimensions and colour; conflicting information to compostability: compostable regarding EN 13432 (not clear if it is for all colours or only for the green)

4c) Based on this information, which among the following is true for this bag?

a) This product is bio-based.

b) It cannot be said with the available information.

c) This product is not bio-based.

Questions (Slide 13/Page 5)

Question 5:

You prepare steaks and chips for your friends. For the chips, you use a lot of olive oil. After preparing the meal, you let the used oil cool down. The next day, you bring the used oil to a collection point, where a tank for used cooking oil is placed and regularly emptied by the city. To which bioresource category would you assign your used cooking oil?

a) Quaternary bioresource, because the oil was used by you for cooking and can be further used for something.
b) Tertiary bioresource, because the amount which is produced in the kitchen is rather small and the oil is polluted with potato residues.
c) Secondary bioresource, because the used oil is collected in a tank and the tank contents are used in a close-by biorefinery for biofuel production.
d) Primary bioresource, because the oil was made from olives from a farm close-by.

Question 6:

Which secondary bioresource is generated in agriculture as by-product from milk production by dairy cows?

a) Eggs, which the farmer can sell in the nearby market.
b) Calves, which the farmer can give to a slaughterhouse.
c) Grass, which the farmer uses to feed the cows.
d) Manure, which the farmer can use to fertilise crops.

Question 7:

Which of the following resources are counted as primary bioresources?

a) Insects, which are grown on food waste to produce feed for animals.
b) Insects, which are kept in a terrarium in a zoological garden.
c) Insects, which are fed with chicken feed to produce food for humans.
d) Insects, which live on trees and are used by bees to make honey.
e) Insects, which were manually collected from agricultural plants, since they destroy the harvests.

Answers:

Question 1: a) This product is bio-based.

Question 2a: b) It cannot be said with the available information.

Question 2b: b) It cannot be said with the available information.

Question 2c: c) This product is not bio-based.

Question 3a: b) It cannot be said with the available information.

Question 3b: b) It cannot be said with the available information.

Question 3c: c) This product is not bio-based.

Question 4a: b) It cannot be said with the available information.

Question 4b: b) It cannot be said with the available information.

Question 4c: b) It cannot be said with the available information.

Question 5: a) Quaternary bioresource, because the oil was used by you for cooking and can be further used for something.

Question 6: b) Calves, which the farmer can give to a slaughterhouse.

Question 7: a) Insects, which are grown on food waste to produce feed for animals. c) Insects, which are fed with chicken feed to produce food for humans.