BIOECONOMY

HANDBOOK OF THE FUNDAMENTALS

FOREWORD

This handbook is described as the outcome of the bachelor's thesis by the same writer. The handbook of bioeconomy fundamentals is created with the hope that academic readers will educate themselves about this interesting topic. The writer himself has acknowledged that this handbook may have several mistakes as well as a rigid writing style. However, in all sincerity, the writer hopes that his readers could tolerate these matters and enjoy the reading.

Nhan Thai

CONTENTS

WHAT IS BIOECONOMY ?

Bioeconomy has several names known as bio-based economy or knowledge-based bio-economy. This concept refers to an economy where its materials, chemicals and energy are taken from biologically renewable resources (McKormic & Kautto 2013, 1-2).

Bioeconomy has the potential to respond environmental, social and economic challenges. This concept provides best opportunities for firstly, biotechnologies that can be applied in production for higher productivity, for example, in agriculture to meet future demand and secondly, transformation from fossil-based economy into bio-based economy with renewable resources. During the concept development, the term "knowledge-based" was also added into the definition as "knowledge-based bioeconomy". The knowledge-based bioeconomy aims at achieving an economic development with "high-technology industries, which requires investments in innovation and highly skilled labours" (Birner 2018, 20). Besides, the development of this concept also emphasizes the two perspectives of bioeconomy: "the resource substitution" and "the biotechnolo-gy innovation". The resource substitution perspective focuses on the scarcity of fossil fuels. This calls for the substitution of fossil resources by renewable resources. Meanwhile, the biotechnology innovation perspective highlights the role of biotechnologies in economic development, employment, energy supply, and the improvement in living standards (Birner 2018, 19-20).

Bioeconomy has developed into a global concept. There is an increasing trend that not only industrialized but also developing countries have had their bioeconomy-related strategies and policies. Regarding scientific literature, more and more publications relat-ing to bioeconomy topic have been considerably risen as well (Birner 2018, 21- 22).

BIO-BASED RESOURCES

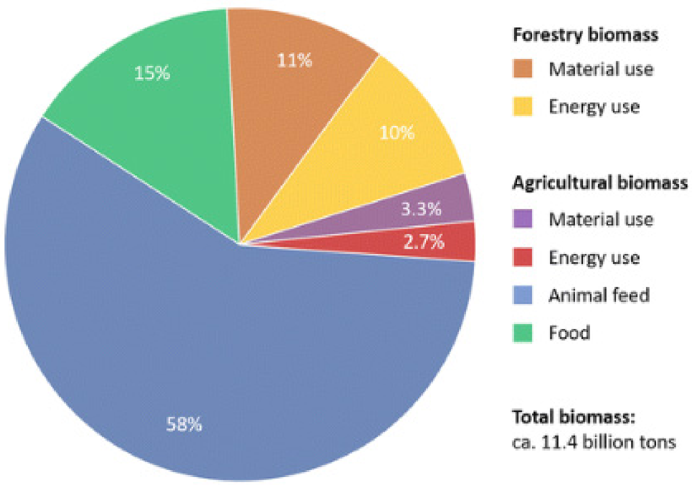
BIOMASS ORIGIN

Biomass as known as biobased resources originate from organic sources: plants, animals, microorganisms, algae, and organic wastes. Biomass is formed through the pro-cess of photosynthesis in which plants and green algae transform light energy into chemical energy. Oxygen, sugars are the main products of photosynthesis. Depending on biomass origin and specific demands, bio-based products can be achieved by relevant methods (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 77).

BIOMASS CHARACTERIZATION

The classification of biomass re-sources can be based on their origin (plants, animals, algae or microor-ganisms). When it comes to biomass products, their characteristics and production requirements are both very distinctive from each other. This is also true for ethical perspectives such as “meat” biomass is not accepted by the plant-based community. Biomass resources can also be classified by their sectors which they are made from for example agriculture, forestry, fishery, and aquaculture. The competition for food supply brings out the necessity of the best use of biomass. Hence, “edible” and “non-edible” biomass classification is also needed. Biomass major component e.g. sugar, starch, oil, protein, cellulose is the most appropriate criterion for the biomass classification in terms of biobased product chains. Physical condition is also considered as one criterion for classifying biomass. These physical conditions can be “wet”, “dry”, “solid” and “liquid”. The requirements for e.g. processing and storage are determined by biomass physical condition. (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 80-82).

The diagram shows the total estimated global biomass and its use from the forestry and agricultural sector. There are about 11.4 billion tonnes of biomass produced every year, which include wood (18%), agricultural production (40%), pasture (30%) and by-products (12%). Approximately three quarters of agricultural biomass is used for ani-mal feed production. (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 83).

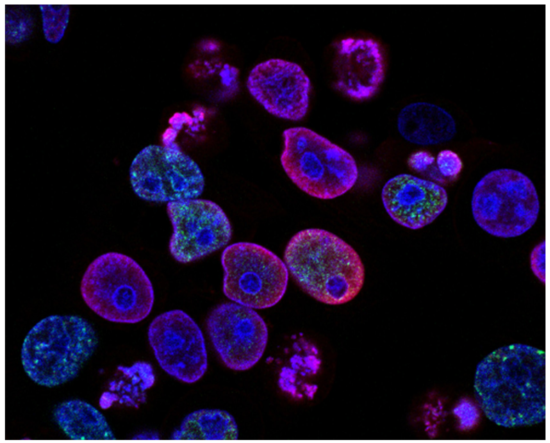


BIOMASS CHARACTERISTICS IMPROVING TECHNIQUES

BREEDING

Breeding is “the application of genetic principles in animal husbandry, agriculture, and horticulture to improve desirable qualities” (Website of Britannica). This method is still one of the most important ways for producing food sustainably and sufficiently. Different crop characteristics such as yield, resistance to pests and diseases, fertilities, adaptation can be achieved through breeding methods. There are two majors of them: “conventional” and “genetic engineering” methods. The former aims to improve either varieties or breeds. The latter is used to modify organism’s genome (genetic material) with biotechnological techniques (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 84).

GENETIC ENGINEERING



Genetically modified organisms (GMOs) refer to organisms whose chemical structure has been modified to achieve desired characteristics (Website of Britannica). Genetic engineering techniques can be widely applied to crops with the purpose of chemical structure modification. This method brings several advantages; however, GMO production is not certified in organic agriculture and accepted around Europe (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 84).

BIOLOGICAL KNOWLEDGE

Biological knowledge is the process of combining biological information and interpreting its meaning. This process is carried out by bioinformatics which applies computational and mathematical tools to organize, store and analyze biological data. Biological knowledge is valuable for such knowledge-based bioeconomy because of the practical data for developing processes in for example pharmaceutics and crop productions (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 85).

SYNTHETIC BIOLOGY

Synthetic biology is the application

of genetic engineering and biotechnology to develop novel, non-natural biological components, and systems with desired characters or redesign existing biological systems for new purposes. Synthetic biology provides new prospects for bioeconomy, for example, more economical production of some products, products that cannot be produced by naturally biological methods (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 86).

VALUE CHAIN

The Porter's value chain describes a process included various activities from a product/service conception to final consumers and disposal after use. The bio-based value chain shares the same idea with the original value chain definition. However, as the intricate processing procedure of raw materials in bioeconomy, which means their inclusion in the value chain would cause the incomprehension. Therefore, the biobased value chain below is the simplified version with major activities including primary production, conversion, and markets. In this way, it would be easier to read, yet, cause the loss of information. In addition, a value network that integrates several value chains enables the demonstration of such products

SIMPLIFIED VALUE CHAIN

made from various raw materials (Zörb, Lewandowski, Kindervater, Göttert & Patzelt 2018, 87-89).

Value-added chain is another name of value chain. In a value-added chain, additional information such as product chain, process chain, information flow is included. Product chain illustrates the transformation from raw material(s) to a final product. Process chain shows extra processing phases to achieve essential intermediates. Information flows are those about economic, social, and environmental impacts that originate from a product. From an economic viewpoint, the value-added chain assists stakeholders in understanding the cost structure and socioeconomic value of a product in a detailed manner (Zörb, Lewandowski, Kindervater, Göttert &Patzelt 2018, 88-89).

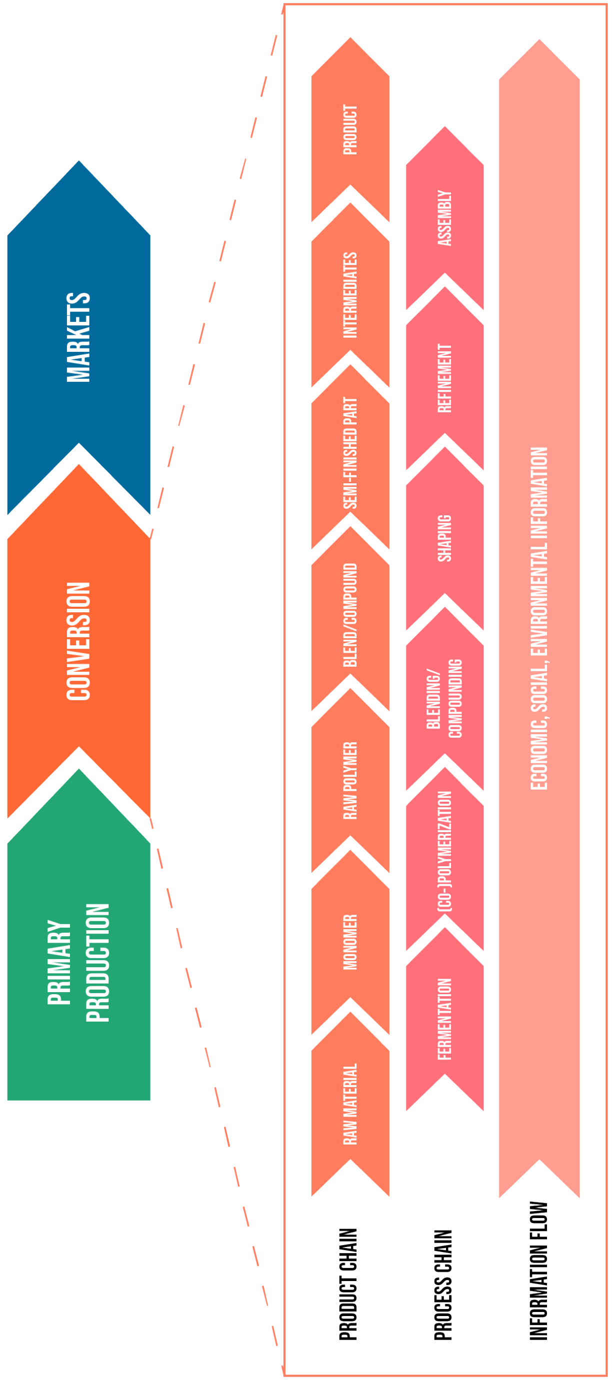
DAIRY PRODUCTION VALUE CHAIN

BIOGASS VALUE CHAIN

PAPER VALUE CHAIN

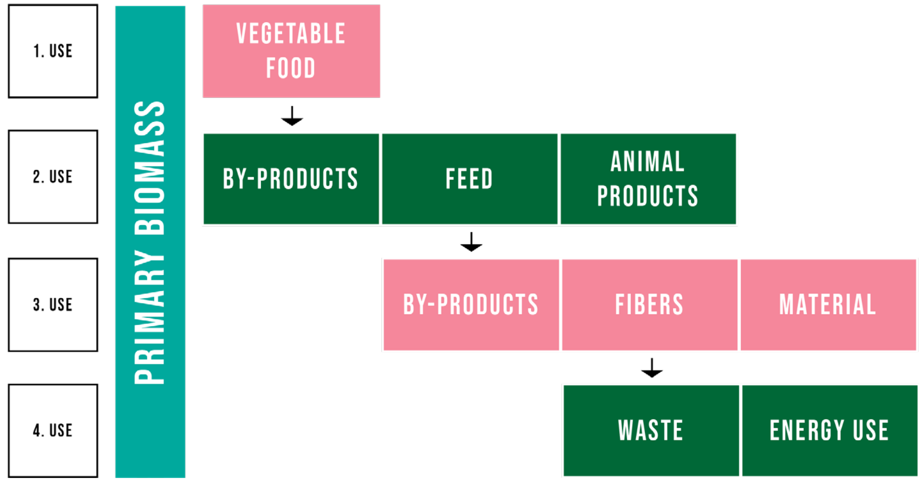
BIOBASED VALUE CHAIN CHARACTERISTICS

As the bioeconomy aims to use renewable resources sustainably,



SIMPLIFIED VALUE CHAIN WITH PRODUCT CHAIN, PROCESS CHAIN AND INFORMATION FLOW OF BIO-BASED PLASTICS

cascading use is believed to hold potential for this purpose. Cascading use is the maximization of renewable resource usage. Additionally, cascading can be considered as the multi-purpose use of biomass and the high-value biomass applications whose prioritization of biomass use is for foodstuff or healthcare purposes. One of the most prominent applications of the cascading approach is biorefinery, whereby biomass can be used efficiently to produce bioenergy and bio-products through different conversion processes (Zörb, Lewandowski, Kindervater, Göttert &Patzelt 2018, 90).



CASCADING USE OF PRIMARY BIOMASS

Characteristics of the biobased value chain are mainly received from the original resources. Agricultural and forestry biomass sectors are typical examples. They are all impacted by environmental conditions, therefore, the production processes have seasonal patterns. Besides, transportability is also considered as another typical pattern as the low density and perishable character of biomass. This shows a huge contrast to the fossil-based production processes (Zörb, Lewandowski, Kindervater, Göttert &Patzelt 2018, 93).

PRIMARY PRODUCTION

Primary production is a process occurring inside living organisms, which utilizes autotrophs from atmospheric and aqueous carbon dioxide (CO2) to synthesize organic substances. Primary productivity indicates the rate of converting energy into organic substances, which is affected by both internal and external factors. Moreover, this indicator also varies from species. Due to the growing bioeconomy that requires a tremendous demand for biomass supply, higher productivity is always expected. Yet, the debate on the use of biomass for food supply and other uses such as energy and materials creates clear rules to determine the priority of biomass production and use:

- Potential biomass should not be in the conflict with food production

- Biomass should not be produced in areas of conservation

- Biomass should be produced more efficiently through leveraging available resources as well as residue streams and improving conversion techniques (Lewandowski, et al. ... 2018, 97-100).

Agriculture and forestry are the two major biomass production sectors. Fishery, aquaculture, algae and microorganism sectors produce smaller quantities consecutively.

AGRICULTURAL PRODUCTION

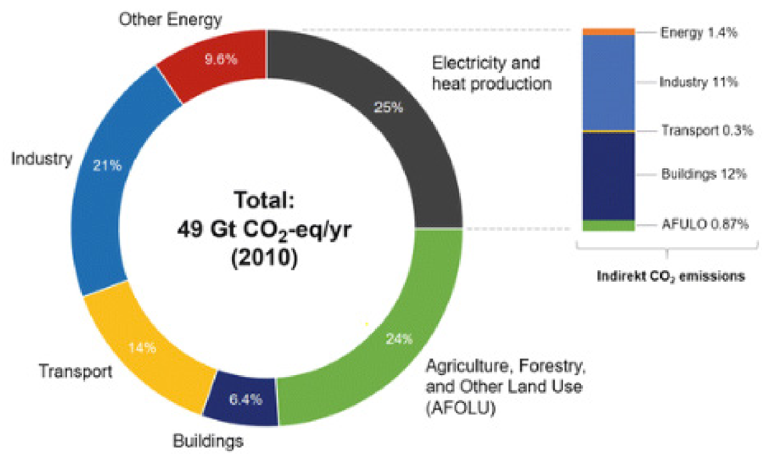
Agriculture is the cultivating of plants and the raising of livestock to produce food, feed, fiber and other desired products such as biomass for material and energy use. These agricultural productions are organized by farming entities inside the agroecosystem. Agroecosystem can be described as a natural ecosystem that is modified by man for agricultural activities such as crop production or animal husbandry (Website of ScienceDirect). There are several factors impact on the efficiency of agricultural production systems:

- Production activity: crop, livestock or mixed production

- Form of organization: family farm, industrial farm, etc.

- Climatic and environmental conditions

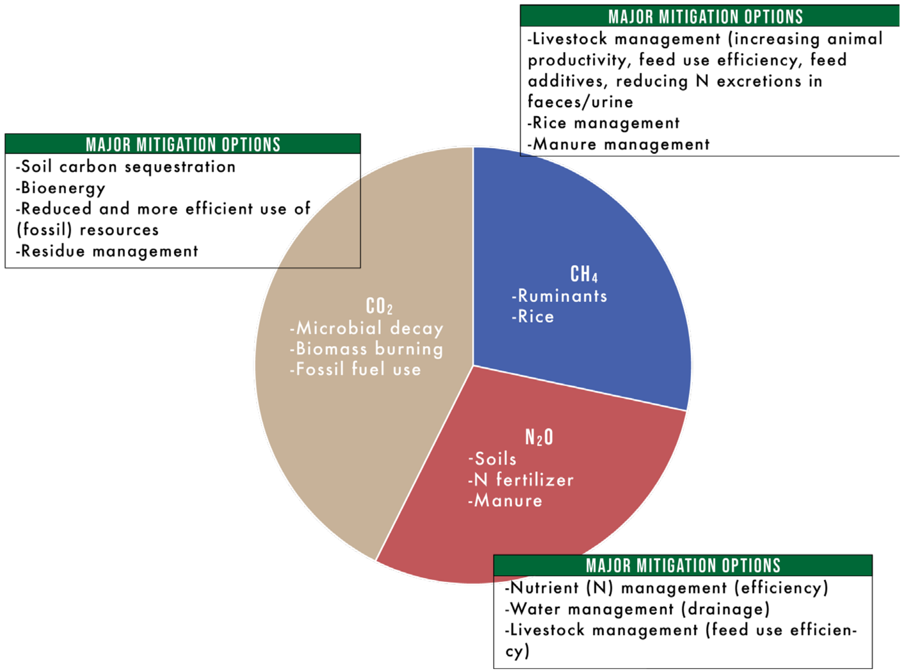
- Socio-economic factors (land availability, farm and market structures) (Lewan-dowski, et al. ... 2018, 102-103)



AGRICULTURE AND CLIMATE CHANGE

The mitigation of greenhouse gas emissions is crucial to cope with climate change. The sector of agriculture, forestry, and other land use account for 24% of greenhouse gas emission around the world. Agricultural activities have a tremendous impact on the climate change due to the massive contribution of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O). These main greenhouse gas emissions come from different sources and have various options for the mitigation as shown in Figure 10. The main CO2 sources are from bio-based litter combustion and decomposition, and fossil fuel use in production. Ruminant livestock is the main cause releasing most of CH4 through their digesting process. Manure use and rice cultivation also contribute a huge portion of this greenhouse gas. N2O is primarily from the chemical reaction of nitrogen (N) in soil and manure; and the high-level use of nitrogen fertilizer (Lewandowski, et al. ... 2018, 125).

The emission of greenhouse gasses in agricultural production should be reduced by:



TOTAL EMISSIONS FROM GLOBAL AGRICULTURE: 5.1-6.1 GT CO_2EQ/YEAR

- maximizing the productivity in agricultural production by better conversion techniques; utilizing available resources, etc.

- efficiently managing agriculture inputs for example fertilizers, pesticides, ener-gy, machinery into the production system

- enhancing land management, residue management, water management, etc.

- considering bioenergy as an alternative in production (Lewandowski, et al. ... 2018, 125).

FORESTRY

Forests take up mostly 30% of the world's surface and are one of the world's most important ecosystems. Forests store a remarkable carbon volume that is estimated as much as the atmosphere. Furthermore, forests have several roles relating to human livelihood, biodiversity conservation, protection for soil and water, building materials, natural resources provision; for example, food, feed, energy. Forestry is the practice and science of understanding and managing forests. This includes the

responsible use of natural resources that are associated with forests. Forests have an essential role in the present and future bioeconomy as the provision of huge sustainable and renewable resources. Moreover, forests are of few biggest carbon sinks and play their role in mitigating climate. Thus, a general forest definition should be considered these listed criteria:

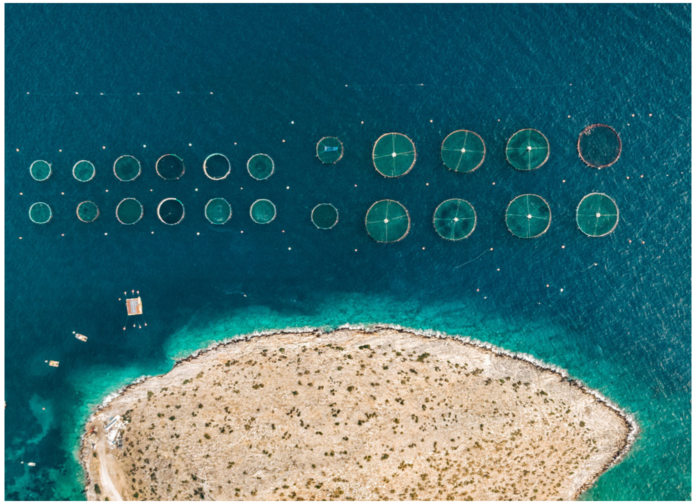
CHEMICAL COMPOSITION OF WOOD	
CARBON	50%
OXYGEN	43%
HYDROGEN	6%
NITROGEN	1%, incl. minerals

- Forest is an area covering a large collection of trees that are ever-lasting, woody and erected.

- Forest has its own "forest cli-mate" that is much different from the open land's so that tempera-ture and humid-ity are relatively balanced. Wind speed is signifi-cantly reduced. Soil properties are much better in terms of or-ganic matters.

- Different types of forests are characterized by different hab-itats and ecologies that support the existence of plant and animal community (Lewandowski, et al. ... 2018, 128).

Forests not only provide the habitats for human livelihoods and animals, but also protect watershed; prevent soil erosion, and mitigate climate change. Wood is the major physical resource that has changed mankind's history as an energy source. Wood as a primary element for supporting human livelihood remains the same until now. In bioeconomy, it is essential to understand the composition as well as the features of wood. Three main components of wood are cellulose; hemicelluloses and lignin. Regarding the chemical perspective, wood contains carbon, oxygen, hydrogen, nitrogen and some minerals. With distinctively physical and chemical characteristics, wood can be applied for a wide range of purposes. Beside energy use, wood is such a multi-purpose material for such as construction, paper, furniture, ornament, food materials (sugar, flavoring agent, etc.) (Lewandowski 2018, et al. ... 136-138).



In respect of sustainable forest management, the exploitation of forests for the economic purpose should be under control. Many parts of the world's forests have been dramatically lost due to the anthropogenic impacts. This tremendously affects the biodiversity, the ecosystem, and the livelihood of many species including humans'. For future bioeconomy, forest degradation would be a huge threat. Therefore, forestry management regulations should be developed and implemented, especially in developing countries or tropical areas where forests are one of the main sources of human livelihood. Additionally, the promotion of world challenges and awareness of people towards the environment and forests would help to deal with the sustainable use of forests (Lewandowski 2018, et al. ... 141-144).

AQUACULTURE

Aquaculture can be understood as the farming of aquatic animals with economic, recreational or other purposes. Aquacultural activities take place in water environments that can be rivers, ponds, lakes, ocean, or man-made closed systems inland (Website of National Oceanic and Atmospheric Administration).

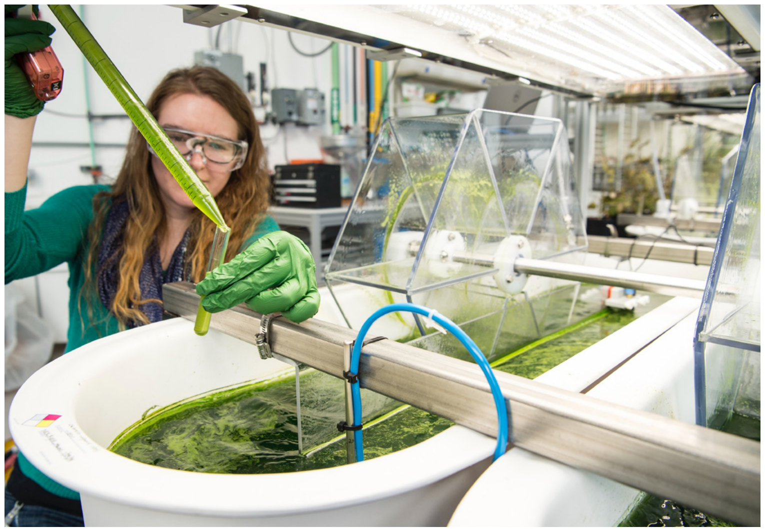
Aquatic animals are rich with nutrients and provide a healthy diet; therefore, the demand for aquatic food consumption and feed products has increased rapidly. The high demand for aquatic food consumption has led aquaculture to the number one food production with the fastest growth globally. At the same time, the biomass from the aquaculture sector has not changed that much over the past decade. When it comes to aquaculture production systems, it can be generally classified into three major systems based on their intensity: extensive, semi-intensive, and intensive. Aquaculture production systems highly associate with spatial factors such as production location, produc-tion scale (Lewandowski, et al. ... 2018, 145-147).

Extensive aquaculture applies for growing aquatic organisms such as mussel, oyster, seaweed with low demand for external inputs (feed, fertilizers) and mainly grow by natural feed sources. The stocking density is low due to limited natural feed resources in natural environments. These extensive systems do not require a high level of technical equipment as well as management. This method can only be applied if natural water areas are rich and not contaminated, which is important for biological preservation purposes. **Semi-intensive aquaculture** happens in either natural or constructed pond environments where aquatic organisms such as catfish, carp, prawn are grown by both natural feed supplies and external supplies through fertilizers. The stocking density is much moderate compared to the intensive type of aquaculture. The medium management level is the optimum requirement in semi-intensive aquaculture. Extensive and semi-intensive aquaculture often takes advantage of polycultures that combine several species in the same environment. **Intensive aquaculture** uses for producing carnivorous aquatic animals for example shrimp, salmon in monocultures (one aquatic animal is grown at a time) by external feed resources only. This intensive system requires high technical management. Net cage and inland flow-through systems are main man-made environments applied in intensive aquaculture (Lewandowski, et al. ... 2018, 147-149).

Considering the various types

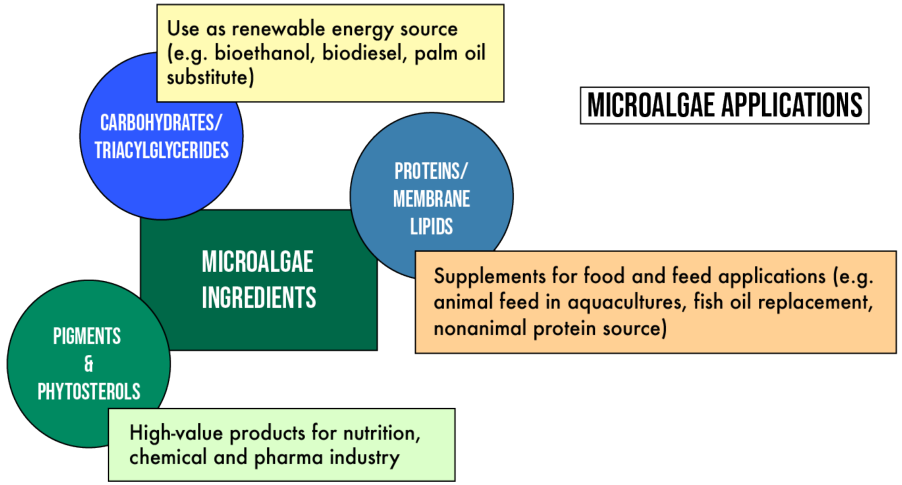
and scales of aquaculture production systems, aquaculture has a huge impact on the environment. Additionally, the continuous growing demand for food consumption and feed would make aquaculture production more intensive. Thus, the focus on environmental, economic, social sustainability in aquaculture is extremely important. Risk management is necessary for aquaculture production to prevent potential risks as well (Lewandowski, et al. ... 2018,153).

MICROALGAE



Microalgae are known as a group of plant-like, single-cell organisms and estimated around 300,000 species existing on Earth until now. They are the most important oxygen and biomass producers. Microalgae produce approximately 50 % of the global oxygen. In terms of biomass production, biomass productivity of microalgae is usually five-to-ten times higher than of any higher plants. In addition, freshwater consumption is one of those advantages in cultivating microalgae because of their ability to grow in brackish and coastal seawater. The microalgae production process is distinguishing from land-based animals since the growth is generally in controlled environments. Light is considered as the most important factor in the microalgae cultivation. Microalgae use light energy to transform carbon dioxide (CO_2) into high-value compounds (proteins, omega-3 fatty acids). It also depends on the species and the desired products that the cultivating system would be selected for certain purposes. They can be tubular reactors, flat-panel reactors or open ponds (Lewandowski, et al. ... 2018,154-155).

Microalgae cultivation provides many materials that can be used for food and feedstocks, beauty products, and pharmaceutical ingredients, energies. Figure 12 shows typical compounds that can be applied in various sectors. In bioeconomy, microalgae biomass production is relatively challenging and high-cost since microalgae biomass contains more than one component that is needed for a specific application such as proteins and omega-3 fatty acids for food applications. Additionally, the productivity depends on the microalgae origin as well as the cultivation method. Hence, microalgae biomass in bioeconomy should be approached efficiently and completely (Lewandowski, et al. ... 2018, 157-160).



PROCESSING OF BIO-BASED RESOURCES

Bioeconomy attempts to convert or process bio-based resources into as many products as possible that can be applied in different sectors, for example, food, feed, energy, and materials.

Food supply production is the most fundamental and traditional function of bio-based resources. The industrialization has majorly changed how food is processed, technologies applied in these processes, and how they are packaged and preserved. In a general sense, the development of food science and technology elevates food matters when it comes to physical, chemical, and biological processes that improve food quality and safety. Our current economic system heavily relies on fossil resources (crude oil, coal, natural gas). In bioeconomy, renewable feedstocks (plants mostly) are the main resources to produce bio-based materials. At the same time, the biorefinery is one of the major concepts to replace oil by biomass to produce energy and chemicals. Biorefinery concepts develop new methods for converting biomass into fuels, energy, and materials that can be substituted for fossil-based products. Besides biorefinery, thermochemical, and biochemical conversion are both initiated from biorefinery concepts but less in demand. In respect of energy and mobility, wind, solar, and geothermal energy have great potential. Though, renewable feedstocks are still the best choice for these purposes (Lewandowski, et al. ... 2018,179-180).

Sustainability can be understood in a wider social context known as sustainable development. Sustainable development involves economic, environmental, and social factors. In other words, sustainable development aims at the balance between the development of the current generation and the security for the coming generations. Thus, this concept of sustainable development has a great influence on the formation of bioeconomy principles that cover these three dimensions (Hahn 2018, 250-251).

Sustainable development is about the integration of economic, environmental, and societal objectives. The United Nations has pointed out 17 sustainable development goals that need to be achieved for a better future. These goals cannot be reached if we focus solely on a single aspect. Instead, the requirement for the integration of economic, environmental, and societal factors is vital for this sustainable development achievement.

Furthermore, the promotion of sustainable development and sustainable development goals need the interaction of several actors. A company should embrace the concept of sustainability management which is ideal for its financial bottom line. The substantial support from different investors and shareholders is needed for sustainability management. Policymakers should integrate sustainable development goals into the regulations and policies. Organizations encourage their employee sustainable performances; influence shareholders through sustainable management. Consumers improve their awareness and change their behavior to contribute to sustainable development (Hahn 2018, 249-255).

Regarding societal transformation, bioeconomy is one essential element that can facilitate this transformation. The demand for a bio-based economy has been growing recently as its value and consumer's preferences. Hence, the requirement of a transfor-mation from a current economic system into a new system that highlights the economic, environmental, and social sustainability is certain. Bioeconomy, in this regard, shows its potential to make this transformation happen (Birner 2018, 28-30).

WEBSITE OF SUSTAINABLE DEVELOPMENT GOALS KNOWLEDGE PLATFORM

BIO-BASED MARKET

Bio-based products have been received lots of attention due to the finite fossil resources and climate crisis. For the EU market only, the bio-based product sector has been declared as the most potential area for sustainable future growth. However, bio-based market growth generally does face several limits.

Nowadays, the environmental impacts caused by the fossil-based industries concern the consumer more and more. It is unavoidable that natural resources could not fulfil future demand. An economy that does not rely on fossil-based resources; protect and preserve the environmental values; mitigate climate change, and secure the well-being of the next generations should be created. The bio-based market which has similar characters, thus, has developed as a potential sector in the market. In contrast, the bio-based market development cost is much higher that of traditional markets. This practice shows that bio-based products struggle to gain its market share because of not only cost factor but the socioeconomic situation. In addition, there is still a shortage of standards, certifications and labelling programs for biobased products that differentiate their higher value and prices towards traditional products (Urban, at al. ... 2018, 233-235).

From the supply point of view, the development of bio-based market responses many sustainable development goals. The dependency on fossil resources as well as oil-producing countries would be reduced. Plus, several major environmental problems would be slowed down by climate change prevention, non-biodegradable wastes reduction or landscape preservation. Additionally, governmental support through new policies and regulations is a key factor for the bio-based market success. And then, new technologies play their role in facilitating the new generation of products that are sustainable. Alongside these prospects, the shift to a bio-based market would require continuing effort to maintain this sector in the whole economy. Besides, the conflict between food security and bio-based materials poses another threat to the bio-based market. Although bio-based products are sustainable, they are still less competitive than traditional products due to higher market prices. In terms of productivity, bio-based production is much complex and time-consuming so that high productivity is hard to achieve. Therefore, continuous research and development are essential for the competitiveness of the bio-based market (Urban, at al. ... 2018, 233-235).

BIO-BASED PRODUCTS

In 2008, the global agricultural land use was allocated 18% for food production, 71% for animal feed, 4% for biofuel, and 7% for biomaterials (Urban, at al. ... 2018, 239).

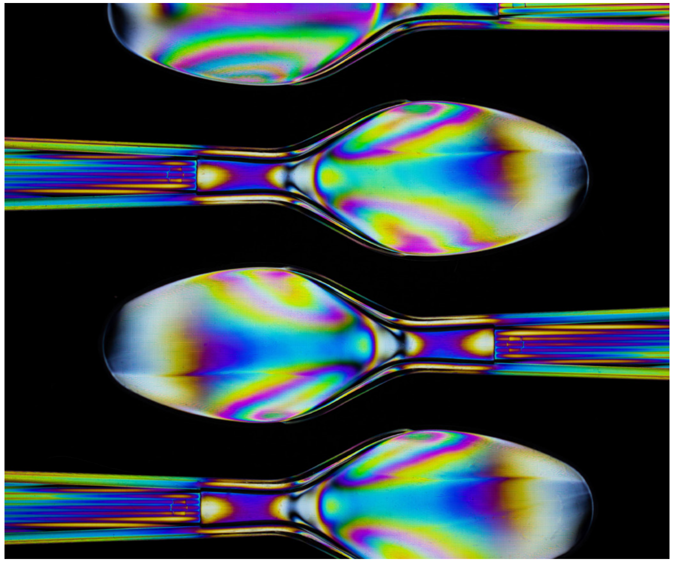
According to OECD definition, biobased products are those made from biological resources, forestry materials, and renewable agricultural materials which can be from plants, animal wastes, and marine materials. Food and feed are not counted as bio-based goods in this case. Biobased products can be categorized into three major groups: biofuels, biochemical, and biomaterials as shown in Figure 10. Biofuels market which has existed for mostly three decades receives more attention and is more prominent than biochemical and biomaterials. Both biochemical and biomaterial markets are considered as infant industry but gradually growing with the market recognition (Urban, at al. ... 2018, 233-236).

Biofuel has been present in the world long ago, however, cheaper fossil-based energies made the market entry much challenging for bio-based fuels. Biofuel, on the other hand, is the ultimate solution to tackle spiking oil prices and climate change. Global liquid biofuel production has drastically increased during the last three decades. Ethanol and biodiesel are those two well-known liquid biofuels. Figure 16 illustrates the development of ethanol and biodiesel production from 2007 to 2015. It is estimated that the total amount of global biofuel production was 146 billion litters in 2015, with 80% of ethanol production. Biofuel production is accounted for 1% of the world's cropland in 2016. North America was the largest supplier, followed by Latin America including the Caribbean and European Union respectively during this period. The pro-duction of biodiesel and ethanol is predicted to continue increasing by 11.1% and 31.1% in 2025 (Urban, at al. ... 2018, 235-236).

Renewable natural gas as known as bio-methane is one of the potential bio-based gasses that could be widely used in transportation, electricity and heat generation (Website of National Geographic). The development of bio-based fuels (liquid-based and gas-based) brings about a new horizon in clean energy and solutions for global challenges such as climate change, fossil resource exhaustion.

In respect of the biochemical market, more and more bio-chemicals have been produced from biomass nowadays. The diversity of biochemical sets the standard for the classification of the biochemical market. The total sale of bio-chemicals made from bio-based materials in the chemical industry soared up to EUR 48 billion which only represented nearly 3.47% of the total output in 2007. EU 27, North America (Canada, the U.S., and Mexico-NAFTA), and Asia were the strongest players in this bio-chemicals market with the contribution of up to 90% of the global sale. Meanwhile, other parts of the world accounted for 10%. Active pharma chemicals, cosmetics, organic chemicals are those three dominant sectors in the biochemical market as shown in Figure 19 (Urban, at al. ... 2018, 238).

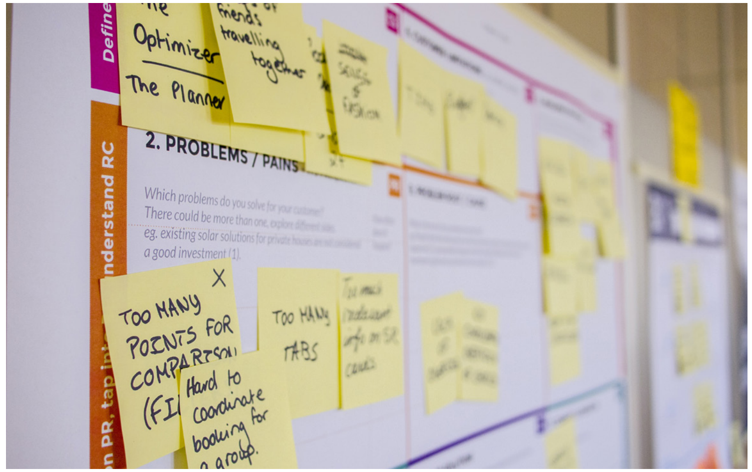
The EU is the most dominant player in this market, which is followed by the U.S. and Asia. In 2013, the bio-based chemical product amount was estimated at around 6% of the total chemical products (Urban, at al. ... 2018, 238). For the EU market, it is ex-pected that the bio-based chemical market annual growth rate could reach approximate-ly 3.6% during the 2019-2025 period (Website of European Commission).



In the biomaterials market, bioplastics gain the most share and quickly grows. Bioplastics are made from renewable sources such as starches, vegetable fats and oils, and cel-lulose. In 2013, bioplastics only accounted for a very small fraction of the annual plastic amount produced around the world around 1% of 300 million tons of global plas-tics. However, the recent high demand for bioplastics has boosted bioplastics production at around 4.1 million tons in 2016. This amount is predicted to reach 6.1 million tons in 2021. Asia was the leader of the 2016 bioplastics market with 1.81 million tons. The other two players Europe (1.31 million tons) and North America (0.97 million tons) followed behind. In 2014, about 1% (0.68 million hectares) of the world's agricultural land was used for bioplastics production. Bio-based Polyethylene Terephthalate (PET) and Polylactic Acid (PLA) are the two domi-nant and fastest grown biobased plastics in the bioplastics industry (Urban, at al. ... 2018, 238-239).

ENTREPRENEURSHIP IN BIOECONMY

Entrepreneurship is the ability to establish, manage, maintain a business venture along with its potential risks to make profits (Website of Business Dictionary). Entrepreneurial opportunity largely comes from market failures. In bioeconomy, recognizing global challenges that we are now confronting and the limits of the current economy are both important for the development of bioeconomy. Despite the awareness of the planet vulnerability caused by the current economy, business practices are not able to avoid market failures. Governments, therefore, have their roles to support entrepre-neurs to reduce such market failures. Entrepreneurs learn from these failures to find out market opportunities (Kuckertz, Berger & Reyes 2018, 275-276).



The likeliness of bioeconomy providing potential entrepreneurial opportunities is enormous. However, entrepreneurs need to thoroughly evaluate those opportunities to ensure their feasibility as well as profitability. The assessment for entrepreneurial opportunities should consider these questions:

1. Where value can be created for customers?

2. Where the opportunity meets competence and experience?

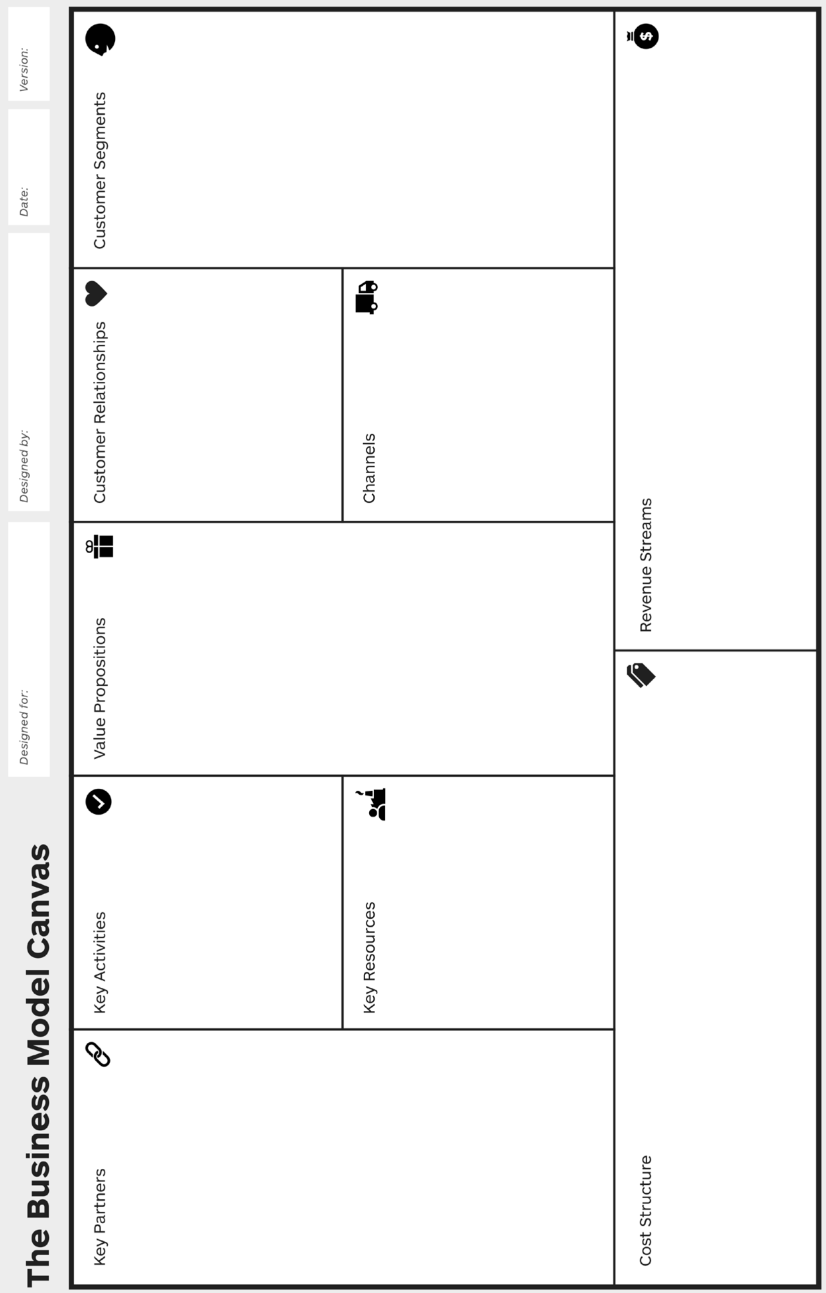
3. Where customers would like to pay a premium for better value?

4. Where opportunities would work in such a growing market?

5. Where risk and potential are balanced? (Kuckertz, Berger & Reyes 2018, 278)

Since the traditional market research approaches often deliver unlikely insights to entrepreneurs about the feasibility of a product or service, developing and testing a product from the early stage of a business is the most likely optimal choice for all start-ups. **Lean start-up method** is one of the most powerful approaches allowing a start-up to reduce unnecessary steps during the start-up process. This method starts with the assumptions of customer desires and potential markets. These assumptions are then validated by future customers. A **minimum viable product** would be finally created from the learning and market failures throughout the start-up process. The minimum viable product serves as a prototype that can bring feedbacks from potential customers so that the start-up can test their assumptions on the actual market needs. In bioeconomy, this practice is extremely crucial because of its nature of innovative products. Both entrepreneurs and consumers should cooperate to come up with a practical business model (Kuckertz, Berger & Reyes 2018, 278-279).

Business model canvas is another great tool to create and develop business through nine important components: customer segments; value propositions, channels; customer relationships; revenue stream; key resources; key activities; key partnerships; cost structure that interact with each other to build on and capture the potential value of a new business. Customer segments are business's future customers whom businesses aim to deliver their products or services to. Value propositions refer to the core value that businesses provide customers to satisfy their needs. Channels are where business-es connect and communicate to their customers or customers can be able to reach a business for their demand. Customer relationships are the kind of relationships a business tries to build on with based on specific purposes. Revenue stream means the money returned from customer segments through value propositions offered to them. Different customer segments bring different revenue streams that contribute to the overall revenue. Key resources are generally those needed to function in a business. Key activities tell about activities that are performed to run a business. Key partnerships include all people and organizations that relate to the operation of a business. Cost structure points out all the



WEBSITE OF STRATEGYZER

costs that are involved in building a business

Bioeconomy offers a variety of entrepreneurial opportunities for new and existing businesses. A market research plan with the assist of these two helpful approaches is ideal for every entrepreneurship to discover market gaps where they can fulfill with ideas of business that show big concern for sustainable development. At the same time, facing difficulties from several factors such as product/service ideas; customer aware-ness; price competition; product development is unavoidable due to the highly innovative nature of bioeconomy.

SUPPORTING TOOLS AND MODELLING

To transform an economy is highly challenging since this practice involves several factors from economic, societal, political, and environmental perspectives. Thus, the need for knowledge-based tools and appropriate strategies is extremely crucial to support this transformation. The development of a potential strategy to transform a system is complex and challenging due to uncertainties. Therefore, access to tools like scenarios is universally important. Scenarios have been widely applied to identify the possibilities when it comes to complex future states. Scenarios strive to look at different future perspectives to define such uncertainties; establish potential future states and development practices. Likewise, other approaches known as integrated model approaches that combine scenarios with models (economic models) would explore the relationship between various components such as resources, production, consumption, markets, sec-tors, and environment (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 290-291).

SCENARIO APPROACHES

Scenarios provide several functions such as knowledge; communication; goal setting, and strategy formation. From a scientific viewpoint, knowledge function is the most essential with two features: analyzing systems through possible consequences of a scenario and integrating social objectives, values, and norms in building scenarios process. If stakeholders share their roles in scenario development, communication function works well in this case as they create a ground for discussions from different fields and perspectives. Then, looking from a strategic perspective, scenarios are ideal for developing specific goals as well as assisting strategy planning (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 292-293).

Scenario approaches are normally classified into three types. **Predictive scenarios** predict the most possible future by such questions "what will happen?" and "what can be expected?". The answer tends to be the forecast of future trends without the consideration of market changes and other relevant decision-making criteria. Meanwhile, **explorative scenarios** analyze possible futures

	PREDICTIVE SCENARIOS	EXPLORATIVE SCENARIOS	NORMATIVE SCENARIOS
CHARACTERISTIC QUESTIONS	What will happen? What can be expected?	What could happen, if...? What is possible?	How can a specific target be reached?
AIM	To predict the most likely future?	To analyse the possible future	Analysis of paths to reach the target
METHOD	Extrapolation of trends	Identification of main drivers	Backcasting

without being likely or desired. The questions like "what could happen, if..." and "what is possible?" would be answered. To develop this scenario, the main drivers of the system development and the interconnection of the elements of the system will be defined. Assumptions about these drivers also play an important role during the progress. This approach mostly works for a long-term period (20-40 years). However, uncertainty factors are still huge obstacles especially in bioeconomy when all drivers of an economy might drastically change over time. Unlike predictive and explorative scenarios, **normative scenarios** aim to reach the target (specific future) by answering the question "how can be a specific target reached?". In other words, a specific target is clearly defined through this scenario, however, this is not the most essential part of this approach. Such social transformations like bioeconomy are the most suitable object of study for normative scenarios. A common method for developing normative scenarios is back-casting which identified targets that are meant to be achieved by analyzing the present and past events to create possible policies for the target (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 293-296). When it comes to transforming a complex system, scenarios are such great tools that assist discussions and decision-making processes. However, scenarios approach could fail to fulfil the formation of the desired future. This is because, firstly, scenarios are neither prediction nor forecast, which will not depict an actual future event. Secondly, scenario findings are usually not objective since scenarios developing criteria are set by scenario builders. Therefore, it is important to follow a set of criteria that are proposed when building scenarios:

- Plausibility: depicted scenarios must show their plausibility but not necessarily consider being likely or desirable.

• Consistency: different scenarios should not conflict with each other.

• Comprehensibility: scenario developments should not be too com-plex.

• Selectivity: different scenarios should present their different future designs.

• Transparency: all assumptions, decisions, and criteria in the development of the scenarios should be thoroughly explained (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 301).

INTEGRATED MODEL APPROACHES

For the scenario analysis, modelling can contribute valuable insights. Until now, there is no holistic modelling approach for developing bioeconomy due to the high degree of interdisciplinary approaches and the matter of economic integration in the bioeconomy.

Economic Models

This will give a brief introduction of economic modelling approaches that are applied in the bioeconomy context where these approaches can be used in biomass demand and

supply.

Macroeconomic Models

Computable general equilibrium (CGE) models whose idea was originated from the equilibrium theory, which can be simply explained as the search for the balance between demand and supply and normally used in trade analysis (An-genendt, Poganietz, Bos, Wagner & Schippl 2018, 303).

Partial equilibrium (PE) models focus on a specific market or sector, which are useful for the thorough understanding of that market or sector (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 303).

Economic Bottom-Up Models

Bottom-up models can be able to answer a variety of questions within the bioeconomy framework. These models mostly depict technical aspects such as technologies, processes of biomass production along with the behaviors of bio-economic players. In addition, these models work at different spatial levels due to the specific interest of the analysis; the availability of biomass; the economic and ecological effects; and the defined boundaries (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 305).

Ecological and Biophysical Models

It is unavoidable that the transformation from a fossil-based economy to a bio-based economy would lead to the increase of biomass demand in both agriculture and forestry. The biomass production in some countries would cause the conflict between economic benefit and environmental system. Moreover, the bioeconomy development must take economic aspects and ecological impacts into consideration. Thus, many models have been developed in response to this.

Biophysical models (process-based models) illustrate biological, geological, and chemical processes that happen in the environment. These models have their focus on different areas. Some analyze how the agricultural and forestry management systems impact the environment. Others examine various scales from plot to global levels of agricultural and forestry activities. Since the demand for agricultural and environmental policy assessment measures, some of these models were developed to meet this specific need. (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 307-308).

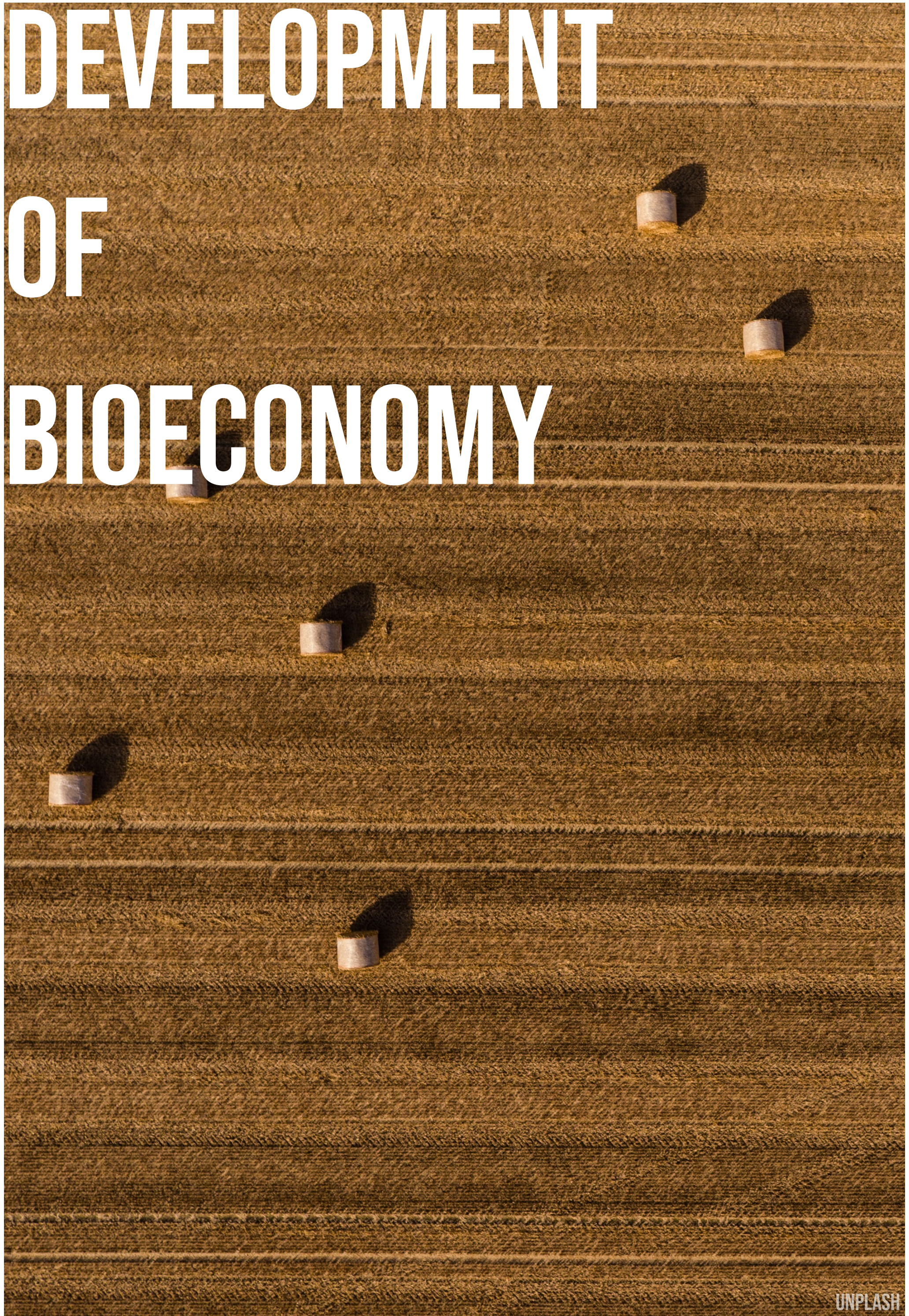
Integrated Assessment Models (IAMs)

Integrated Assessment Models study the interaction between human activities and the environment. They describe socio-economic systems; environmental systems; and the relation between these two systems. IAMs integrate different models so that they can cover several research disciplines and fields such as economics; agriculture analysis; energy analysis; etc. Therefore, the bio-economic developing scenario is more holistic owing to the integration of economic, social and environmental perspectives. (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 310).

THE ROLE OF GOVERNMENT

The government is responsible for maximizing social welfare or improving the quality of life. A responsible government will not ignore the wellbeing of future generations while striving to maximize the present generation's wellbeing. The government has its role in the responsibility to the environment as private sectors themselves cannot fulfil this environmental responsibility. Hence, social welfare can only be fully maximized with tremendous work from the government in different ways. Bioeconomy, at the same time, supports natural resources preservation and mitigates environmental pollution, which are of many sustainable development goals. However, considering the economic sector, private markets cannot successfully achieve these goals. Again, the government needs to support bioeconomy promotion and sustainable development goals (Ahlheim 2018, 317-321).

DEVELOPMENT OF BIOECONOMY



There are great potentials to transform the present economy; heal the planet earth and ensure the welfare of future generations. Despite this fact, such a transition to a knowledge-based bioeconomy would be an extremely challenging task. This section will present major opportunities as well as challenges of this movement.

Bioeconomy provides massive opportunities for growth and jobs especially in such coastal and rural areas. New businesses as well as innovation opportunities in agriculture (food production); aquaculture (blue biotechnology); forestry (integrated biorefineries); bio-product industry (biochemical, biopharmaceuticals) could be set up. However, a huge investment for proper technologies and production would also be a huge constraint for these businesses to start. Additionally, the transition will bring out socio-economic challenges that link to, for example; price sensitivity; farmers' welfare; trade balances (Bourguignon 2018, 3).

Biomass is renewable; however, the available amount of biomass is not yet defined. In other words, biomass remains is a finite resource as a matter of available land and freshwater. Bioeconomy applies different methods such as cascading use to optimize biomass usage. Thus, this could be the solution for material shortage when the world population has been rapidly growing. However, the competition for cultivating land and freshwater to produce biomass might cause adverse impacts on food production and food security. Furthermore, the competition between bio-products vs. petrochemical products; bioenergy vs. fossil energy would be much intense. Traditional products are generally affordable and well recognized by the whole population. However, a step further to bio-products is much challenging as only a portion of the population can access (Bourguignon 2018, 4).

Bioeconomy contributes massively to the goal of sustainable development as it slows down global warming and mitigates climate change by reducing greenhouse gas emis-

sions. The transition to renewable energy would reduce a significant amount of greenhouse gasses. Plus, the development of agriculture and forestry would create more natural sinks for carbon storage. Regarding biotechnologies, many industrial

wastes, plastics, and chemicals could be altered, which not only decreases production wastes and residues but also addresses new methods for better production that helps preserve natural resources. Nonetheless, bioeconomy might lead to carbon emissions in some ways such as deforestation for agricultural land use. Other aspects of life e.g. healthcare can be improved by bioeconomy, but the drawback to these might be the environmental impacts (biodiversity, ecosystem, soil and water quality) that should be underlined through the exploitation of bio-based materials (Bourguignon 2018, 4-5).

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