Chapter 1
Food Waste in the Sustainable Development Framework

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We live in an age of very fast and incomparable planetary change, referred to as the 'Great Acceleration'. It has brought many benefits to human society, such as an overall rise in our health, wealth, food, and security, even if the distribution of these benefits is unequal and we assist to a declining state of the Earth's natural systems. Our ever-increasing consumption is driving what can be considered a new geological epoch, the Anthropocene because for the 1st time in the Earth's history a single species – *Homo sapiens* – has such a powerful impact on the planet. This Chapter deals with the importance of using food waste as feedstock for biorefineries.

1.1 The Triple Bottom Line: "People, Planet, and Profit"

The world is facing important sustainability issues and opportunities. Sustainable development is a challenge, and society has to respond to it in the decades to come. It seems to be a dreadful task. Myriads of necessities have evolved in modern society: food, travel, housing, leisure are only examples of needs influenced by 'culture', differences between individuals and nations. The Information and Communication Technology (ICT) is shaping the society at large as steam power, electricity, and automobility did in the past.

The concept of sustainability is related to the enlightening etymology of this word. It comes from the Latin *sustĭnēre* that means "hold up, support, bear, endure". Anyhow the exact description of a sustainable future is not straightforward.

In this context, 1972 is a cornerstone year. At the UNO Conference on the Human Environment held in Stockholm, Sweden, the concept of sustainability had yet to really take off but, nevertheless, the whole international community agreed to the crucial notion that both development and the environment are not separate issues, and they could be managed in a mutually beneficial way. Environmental concerns were introduced in the political realm. The summit declaration contained the following 26 principles concerning the environment and development.

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1. "Human rights must be asserted, apartheid and colonialism condemned"
2. "Natural resources must be safeguarded"
3. "The Earth's capacity to produce renewable resources must be maintained"
4. "Wildlife must be safeguarded"
5. "Non-renewable resources must be shared and not exhausted"
6. "Pollution must not exceed the environment's capacity to clean itself"
7. "Damaging oceanic pollution must be prevented"
8. "Development is needed to improve the environment"
9. "Developing countries therefore need assistance"
10. "Developing countries need reasonable prices for exports to carry out environmental management"
11. "Environment policy must not hamper development"
12. "Developing countries need money to develop environmental safeguards"
13. "Integrated development planning is needed"
14. "Rational planning should resolve conflicts between environment and development"
15. "Human settlements must be planned to eliminate environmental problems"
16. "Governments should plan their own appropriate population policies"
17. "National institutions must plan development of states' natural resources"
18. "Science and technology must be used to improve the environment"
19. "Environmental education is essential"
20. "Environmental research must be promoted, particularly in developing countries"
21. "States may exploit their resources as they wish but must not endanger others"
22. "Compensation is due to states thus endangered"
23. "Each nation must establish its own standards"
24. "There must be cooperation on international issues"
25. "International organizations should help to improve the environment"
26. "Weapons of mass destruction must be eliminated"

Sustainable development is a concept that was defined by the Brundtland Commission of the United Nations in 1987 (Brundtland Commission 1987) (Robert et al. 2005). The Brundtland Commission correctly argues: "the environment is where we live; and development is what we all do in attempting to improve our lot within that abode. The two are inseparable." According to the Brundtland Commission, sustainable development meets the needs of the actual generation without impairing the capacity of future generations to meet their own needs within a framework of intergenerational equity. In 1992, the term "sustainability" was referred to explicitly during the United Nations Conference on Environment and Development held in Rio de Janeiro, in which major world leaders acknowledged sustainable development as the major challenge. The Rio Summit marked the first international attempt to recognize the necessity for a more sustainable pattern of development. That summit was attended by over 100 Heads of State and representatives from 178 national governments and civil society which adopted an agenda (literally "things to do") for the 21st century, called Agenda 21, which "recognized each nation's right to pursue social and economic progress and assigned to States the responsibility of adopting a model of sustainable development" (United Nations 1992). Agenda 21 is the first action plan for making sure the world will change into a more just, secure, and wealthy habitat where all peoples had access to the natural resources they needed to thrive.

Agenda 21 is divided into 40 chapters, grouped into 4 sections:

Section I: Social and Economic Dimensions.
It is aimed at combating poverty, especially in developing countries, changing consumption patterns, and promoting health.
Section II: Conservation and Management of Resources for Development.
It is aimed at protecting atmosphere, forests, fragile environments, and biodiversity and at controlling of pollution and radioactive wastes.
Section III: Strengthening the Role of Major Groups.
It is aimed at strengthening the roles of youth, women, indigenous peoples, NGOs, local authorities, business and industry, and workers.
Section IV: Means of Implementation.
It is aimed at promoting science, technology transfer, education, institutions, and financial mechanisms.

Notwithstanding the Agenda 21 action plan, unprecedented and interconnected sustainability challenges now face the future development of the world, spanning food security, climate change, pollution, biodiversity loss, poverty, energy, and an over-dependence on non-renewable resources. These challenges are easily predicted to intensify when taking into account that the world population is expected to strongly increase, reaching ca. 11 billion people in 2100 (United Nations, Department of Economic and Social Affairs 2019).

The total energy need in the world is expected to increase by 48% between 2012 to 2040, with estimates of 860 quadrillion kilojoules (KJ) in 2040 (EIA 2016).

Moreover, according to the Food and Agriculture Organization (FAO) there is an annual growth rate of worldwide consumption of all agricultural products of 1.1% per year (Alexandratos and Bruinsma 2012), which translates into an additional 70 million ha of cultivated land required by 2050. Unfortunately, most of the projected lands for expansion in cultivation are in developing countries in Africa, which are often characterized by water shortages. Furthermore, urbanization and agriculture would compete for land availability (Bren d'Amour et al. 2017).

Additionally, the Earth is suffering a big climate change due to an increased global greenhouse gas emissions (GHG). In 2019, total GHG emissions reached a new high of 59.1 gigatonnes of carbon dioxide (CO_2) equivalent. The brief dip in CO_2 emissions caused by the COVID-19 pandemic may provide an opportunity for recovery and for the world's progress towards the Paris Agreement goals of keeping global warming to well below 2 °C compared to pre-industrial levels (UNEP and UNEP DTU Partnership 2021).

Environmental pollution is an additional problem. Air pollution is responsible for the deaths of 3 million people annually, and only one-tenth of the population lives in a city that complies with the WHO air quality standards (World Health Organization 2016).

The ever-increasing volume of solid wastes is an added major concern. The World Bank has estimated that cities will produce 2.2 billion tonnes of solid waste by 2025, with concomitant increases in waste management costs to $375.5 billion (Hassan et al. 2019a).

Most human activities make use of water and produce wastewater. The quantity of wastewater produced and its overall pollution load are unremittingly growing worldwide. Over 80% of the world's wastewater is discharged into the environment each year without treatment (WWAP 2017).

In addition, biodiversity is threatened. The astonishing decline in wildlife populations– a 60% fall in just over 40 years – is a grim memento and the decisive meter of our negative influence on Nature that is underpinned by biodiversity (Grooten and Almond 2018).

Only a holistic approach can be effective in identifying and proposing suitable solutions that tackle these challenges. Strategies that harness renewable resources to maintain ecological sustainability while maintaining economic growth are needed.

In Rio, two decades after the first Rio summit, the "Rio+20" Conference took place; the Leaders from 180 nations attending the United Nations Conference on Sustainable Development reaffirmed their commitment to Agenda 21 in their outcome document called "The Future We Want".

To overcome these unprecedented environmental challenges, during the last UNO Sustainable Development Summit (2015) Agenda 2030 was put forth (United Nations). It re-asserts all of the goals set by Agenda 21 as the basis for sustainable development.

Figure 1.1 illustrates a total of 17 Sustainable Development Goals (SDGS) (detailed by 169 targets) that have been agreed on by 193-member states of the United Nations. People, planet, prosperity, peace, profit, and partnership are the focus of interest of the Agenda 2030 (United Nations).

From Fig. 1.1 it is clear that there is growing attention towards a more integrated vision fully including three pillars of the multifaceted concept 'sustainability' linked to:

1. People and human aspects, such as equity, quality of work conditions, education, health, and respect for human rights. Fair business practices toward labor and the community in which the corporation conducts its business are crucial for coordinating stakeholders' interests and not only shareholders' ones. Aside from the moral trait of being "good" to society, disregarding social responsibility can impair the performance of the business because there are economic costs linked to overlooking social responsibility. Employee relations and fair wages must also be considered. Quantifying these aspects is relatively new, problematic, and fraught with potential subjectivity problems. The Global Reporting Initiative (an

Fig. 1.1 Agenda 2030's sustainable development goals. Reprinted with permission from SGD Permissions. https://www.un.org/sustainabledevelopment/ "The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States"

independent international organization that has pioneered sustainability) has developed guidelines to enable corporations and non-governmental organizations (NGOs) to comparably report on the social impact of a business.

2. Planet and physical aspects, such as preventing depletion of essential resources, their wise management, environmental protection and biodiversity. In this context, the quantitation and reduction of the ecological footprint of a business are crucial. This can be achieved by carefully managing the consumption of energy and non-renewables and reducing manufacturing waste and its toxicity before disposing of it in a safe and legal manner. However, this "cradle to grave" approach to production is not the smartest one since it would be even better if the process residuals are recycled or upcycled in other processes in a "cradle to cradle" approach with the help of digital strategies and opportunities. In a healthy sales stream, a life cycle assessment of products helps decision-makers to know what the product's true environmental cost is from the growth and harvesting of raw materials to manufacture, to supply, to eventual disposal by the enduser. It would be equitable for the business which sells a problematic product with toxic waste to endure part of the cost of its ultimate disposal. Ecologically destructive practices, such as endangering depletions of resources, must be avoided. In the long run, environmentally sound business is not less profitable than hazardous processed. For the quantitation of environmental aspects, the Global Reporting Initiative, nonprofit sustainability organizations, such as CERES, and the Institute 4 Sustainability, among others, provide companies with rigorous environmental metrics that are standardized better than social ones.
3. Profit and economic aspects, such as sound businesses, wise management, and distribution of economic resources also in developing countries, and equity in

trading. Profit is the goal shared by all businesses. Real economic benefits enjoyed by the host society and its economic environment at large must be considered. Within the sustainability framework, profit should be considered as the economic benefit shared by all stakeholders non only the company's stakeholders.

In this perspective, many apparently disconnected topics (such as energy and safety, waste reduction, and economic development) are strictly interconnected within three boundary conditions: social, environmental, and financial.

It follows that "Planet People and Profit" has become a refrain known as the Triple Bottom Line (TBL) framework that enables organizations to take a longer-term outlook and thus evaluate the future consequences of decisions.

Business writer John Elkington claims to have coined the phrase (Elkington 1998). In traditional business accounting, the very bottom line on a statement of revenue and expenses refers to profit (or loss, if the case). Corporations are nowadays requested to perform a full societal costbenefit analysis, thereby taking into account two more "bottom lines" regarding, respectively, social and environmental concerns.

This accounting framework with financial, social, and environmental details has become the dominant approach to public sector full cost accounting. Similar UNO standards apply to natural capital and human capital measurement to assist in measurements required by TBL.

The TBL approach has also been extended to a quadruple bottom line (QBL) approach to encompass a fourth pillar concerning a future-oriented approach (future generations, intergenerational equity, etc.) (Waite 2013). An integrated balance sheet was also proposed to provide a more holistic look into a company's performance (Robert Sroufe 2018), (Eccles and Krzus 2012).

If in the early stages of this process, the demand for sustainably manufactured products was putting pressure on the industries, now corporations are aware of the fact that sustainable products and processes are an economic opportunity. The concept of materials coming from natural biomass with environmental advantages of being biodegradable and/or biobased is becoming very attractive to the industry and to the consumers.

TBL companies can find financially profitable niches that were missed when money alone was the driving factor; ecotourism, fair trade and B corporations (benefit corporations), and social enterprises are common examples of these niches.

The major concern about the triple bottom line is that the three separate accounts cannot easily be added up because the planet and people accounts can not be measured in the same terms as cash profits. This has led to TBL being augmented with cost-benefit analysis.

Sustainable development should recognize the well-being of human systems that is supported by a healthy, natural environment in which future generations have an equal claim on our planet's resources.

1.2 Decoupling of Production from Fossil Feedstock and the Breakthrough of Renewable Resources

The twentieth century saw a colossal growth in chemical manufacturing which fed the world development mostly in an unsustainable way. Energy-intensive and inefficient processes reliant on fossil fuels resulted in unacceptable levels of pollution. The approach to Nature involved exploitation and control over it, and this came at the cost of hazardous operations resulting in a number of well-publicized disasters. The inadequate disposal of huge amounts of waste posed many concerns to public health, and product safety issues led to an exponential growth in chemicals legislation. It's a shame how chemistry has been demonized during the last decades, but it is true that some products typical of the developed world became an emblem of waste, pollution, and ecotoxicity. This is the case of plastics, whose attractive qualities lead us, around the world, to a voracious appetite and over-consumption of disposable plastic goods.

Continued dependence on fossil fuel energy reserves is unmaintainable because world crude oil reserves are limited and dwindling; moreover, they are associated with GHG emissions responsible for major climate change. Fossil energy and raw materials for chemicals are rapidly depleting. There is a serious need to change the industry and human civilization to sustainable habits for assuring a constant improvement of life quality. This is well perceived by consumers who ask for environmentally-sustainable products. Increased restrictions for the use of products with high "carbon footprint" are continuously put forth, industries start focusing on the development of new biobased feedstocks and are now very attentive to the reduction of GHG emission and to the sequestration of CO_2 to comply with legislation aimed at curbing GHG presence in the atmosphere. The concerns over the mounting energy demand and price, as well as environmental pollution from fossil fuel, have prompted research into renewable energy. There is a worldwide trend to produce alternative, renewable biobased fuels and chemicals to those derived from petroleum. By this scenario, the hunt for a sustainable alternative feedstock for fuels and materials for our society continues to grow.

The European Commission (EC) set mandatory targets for an overall share of 20% renewable energy and a 10% share of renewable energy in transport by 2020 (van Dam and Junginger 2011). The European Green Deal aims at improving the well-being of people by (i) making Europe climate-neutral by 2050; (ii) protecting human life, animals, and plants, (iii) cutting pollution (iv) helping companies become world leaders in clean products and technologies (European Commission 2019).

In order to decouple production from fossil feedstock and non-renewable resources, the concept of circular economy was launched in 2010 to preserve physical stocks; it is gaining momentum, and it is seen more than from a research viewpoint (Kiser 2016), shifting our approach to seeing raw materials as assets to be preserved, rather than continually consumed. The linear extract-process-consume-dispose concept is replaced by a restorative and regenerative industrial system by intention and design in order to maintain the value of resources in the economy as long as practically possible. For those familiar with the gross domestic product

(GDP), creating wealth by making things last is the opposite of what economists teach; hence governments and regulators should adopt policy levers, including taxation, to promote a circular economy in the industry. Anyhow, the circular economy idea of turning goods that are at the end of their service life into resources is easily predicted to stimulate the development of green technologies and services, thereby creating new green jobs.

A concrete framework aimed at closing the loop of product life cycles while creating businesses and jobs for people needs the participation of researchers and policymakers, but also involvement and incentives to businesses and people overall.

Manufacturers should also consider the costs and risks associated with the waste generated. Industrial symbiosis by producing innovative and useful products in one industry via utilizing co- or byproducts from another industry needs (i) the development of quality patterns for secondary raw materials to gain confidence in the market; (ii) revision of regulations concerning identification of bio- or waste-based products in the market; (iii) economic incentives for companies to launch and maintain sustainable products in the market, and support recovery and recycling systems (Lieder and Rashid 2016).

This life-cycle thinking is underpinned by (i) the use of renewable energy, (ii) the replacement of toxic chemicals with bio-benign building blocks via the green chemistry approach (Kharisov et al. 2019) to promote human health and environmental protection (Sheldon 2016), (iii) the reuse via recycling or upcycling, (iv) the biodegradability and return to the biosphere.

In this context, the approach to waste needs to be deeply revised also from a linguistic point of view.

According to the Waste Framework Directive (European Parliament 2008) “waste means any substance or object which the holder discards or intends or is required to discard” and food waste is considered a “bio-waste”. Certain specified waste can cease to be waste when it has undergone a recovery, and the item can be used for a specific purpose with clear market demand. The end-of-waste status requires that the item “fulfills the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products”; moreover, its use should not lead to overall adverse environmental or human health impacts.

A by-product is an item that is not intentionally produced during the production process of other products. Byproducts can be produced as a residual of, or incidental to, the production process. According to article 5 of the Waste Framework Directive (European Parliament 2008) an item resulting from a production activity, the primary aim of which is not its production, may be regarded as being a by-product only if:

(a) “further use of the substance or object is certain”;
(b) “the substance or object can be used directly without any further processing other than normal industrial practice”;
(c) “the substance or object is produced as an integral part of a production process; and”
(d) “further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.”

Along with byproducts, co-products are often referred to as valuable secondary goods generated during a production run together with other valuable materials.

The management of process waste is usually presented diagrammatically in the form of a pyramid since there is a hierarchy of actions from the least favorable to the most favorable (European Parliament 2008) to extract the maximum practical benefits from production processes and to dispose the minimum amount of waste within the circular economy framework.

The following waste hierarchy, illustrated in Fig. 1.2, shall apply as a priority order in waste prevention and management legislation and policy: (i) prevention of waste production via superior eco-design of materials, products, systems, and business models; (ii) preparing for reuse via cleaning or repairing discarded products; (iii) recycling or up-cycling via material and chemical sorting processes; (iv) other recovery strategies, e.g., energy recovery; (v) disposal (Kiser 2016), (European Parliament 2008).

Environmental protection principles, technical, economic, and social viability, as well as protection of resources and of human health, are the underpinning pillars of this legislation.

In 2012, the European Commission (EC) put forth the European bioeconomy strategy (Hassan et al. 2019a). It relies on the production of biomass and the utilization of lignocellulosic wastes for their conversion into bio-energy, as well as the production of novel biobased value-added products. At the EU level, the bioeconomy had an annual turnover of 2.3 trillion EURO, and a total employment of 18.5 million people in 2019 (Hassan et al. 2019a). Cultivating the worldwide bioeconomy ethos as the pathway for achieving SDGs is crucial.

The project "Biomass Futures" (2010–2012) assessed the role of bioenergy in meeting Europe's renewable energy targets established by the 2009 Renewable Energy Directive (The European Parliament and the Council of the European Union 2009) for 2020 and provided outlooks to 2030 and 2050. The project estimated the future availability of lignocellulosic biomass. Agricultural wastes are recognized as the largest reservoir of cost-effective feedstocks. On the converse, forestry residues are very expensive because of the lack of commercial harvesting, and many competing uses are possible. The modeling of the biomass supply chain provides data for decision-makers and other stakeholders (Panoutsou et al. 2013).

Fig. 1.2 The Waste Hierarchy (European Parliament 2008)

Decoupling of production from fossil feedstock and non-renewable resources necessarily passes through the biorefinery concept (David et al. 2017). According to the FAO, biorefineries are a pillar of bioeconomic strategy in different countries and regions, including the EU (Hassan et al. 2019a). In the biorefinery biomass is sustainably processed into a range of marketable products (food, feed, chemicals, and materials) and energy (fuels, power and/or heat) (International Energy Agency (IEA) 2009). Compared to fossilbased refineries, biorefineries are an embryonic business, with a portfolio of different biomass feedstocks and a variety of outputs.

There are 67 lignocellulosic biorefineries around the world (only about one-third operating at commercial scale) with biofuel output, while additional advanced biorefineries are under development (Hassan et al. 2019b).

The S2Biom project has projected that a total of 476 million tons of biomass need to be secured to match the demand for biobased products by 2030 (Hassan et al. 2019a). The twin challenge of recalcitrant lignin breakdown and conversion into viable products is a hot research topic with almost 200 annual patent filings and intense publication activity (Toivanen and Novotny 2017).

Biorefineries can be categorized according to a number of different ways. The easiest classification parameter is the raw material used as feedstock.

As illustrated in Fig. 1.3, we are now familiar with four generations of biorefineries, according to the raw material selection.

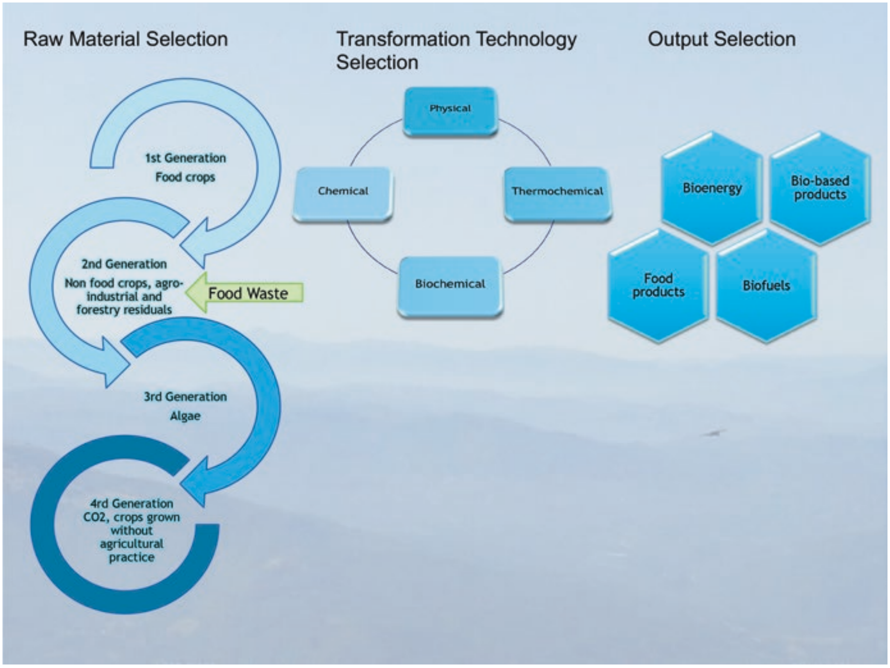

Fig. 1.3 Biorefinery classification according to the raw material selection, transformation technologies, and possible outputs

The first generation of biorefinery relied on food crops, with the main product being biofuel. In recent years, the "food versus fuel" issue for biofuel production using edible food crops and the competition in land use have arisen as a direct consequence of incentivizing energy and oil crops at the expense of food crops (Mohr and Raman 2013). However, the separation of plant biomass intended for the biorefinery from that which may be used in the food chain is a key aspect of future sustainability. For this reason the biorefinery concept has experienced a surge in popularity but also a vocal opposition to the hypothesis of diverting food-grade land and crops for non-food purposes.

The second generation of biorefinery was based on non-food crops (grass, and lignocellulosic wastes, short-rotation woody crops), agricultural and forestry residues (e.g., vegetable leaves, forest thinning, sawdust, sugarcane bagasse, rice husk and bran, corn stover, wheat straw and bran), and agroindustrial or food wastes (e.g., potatoes peel, and fruit peel and stone, spent coffee grounds, apple or tomato pomace, soybean oil cake, spent coffee grounds and so on) (Sadh et al. 2018) (Amaducci et al. 2017) The idea of using the unavoidable wastes arising from biomass processing, farming and food production as the feedstock for the biorefinery is gaining momentum.

The global production of some of these humble wastes is significant; for example, 70–140 thousand tons of potato peels are available worldwide (Wu 2016), and over 4.5 million tons of brewer's spent grain are produced in the USA (Buffington 2014).

Second-generation feedstocks might be recalcitrant and complex lignocellulosic materials that contain variable levels of cellulose, tough substrates, such as hemicellulose and lignin, and other composites. It can be observed that low lignin content and high digestibility render herbaceous biomass crops particularly suitable for second-generation biofuel production (Amaducci et al. 2017). The improvement of technologies to release fermentable sugars represents the major challenge for their efficient and scalable exploitation. In this regard, the utilization of food waste as chemical feedstock is viewed as an interesting opportunity.

The third generation of biorefinery relied on non-food marine biomass, spanning from green, red, and brown macroalgae (seaweed) to microalgae endowed with precious photosynthetic pigments. Seaweeds include *Ulva lactuca, Gracilaria vermiculophylla,* and *Saccharina latissimi*. Seaweeds are currently used in the production of food, feed, and nutritional supplements. They do not require either arable land or freshwater resources to grow, and their ash content can reach up to 60%, while the cellulose content is generally low (Hassan et al. 2019a). Microalgae, such as *Schiochytrium sp., Botryococcus braunii, Nitzschia, Hantzschia,* and *Neochloris oleoabundans,* are generally richer in lipid content compared with carbohydrate.

Algal species are rich sources of oils, and therefore attention has focused on their use for biodiesel production (Mata et al. 2010) and of a number of products of high added-value, such as docosahexaenoic acid (Trivedi et al. 2015). However, for the majority of algal species, a variable efficacy of conversion technologies, high production cost compared with the use of lignocellulosic biomass, and technical difficulties in the scale-up of cultivation operations represent major challenges. The major impediment to any substantial production of algal fuels is the insufficiency of concentrated carbon dioxide they use in their photosynthetic pathways; the development of an ability to almost fully recycle the phosphorous and nitrogen nutrients necessary for algae culture is challenging. These are serious constraints to the commercially-viable exploitation of algae (Chisti 2013).

The fourth generation of feedstocks capitalizes on carbon dioxide, the main pollutant generated through industrial processes, with evident environmental and economic benefits (Mata et al. 2010). Crops spontaneously grown in marginal lands without agricultural activities, such as Jatropha, Castor, and Karanja, could also be categorized under fourth-generation feedstocks (Moncada et al. 2016).

As regards the scale, while high added-value products, such as fine chemicals can be profitably produced in small biorefineries, for biofuel production, the scale must necessarily be large; the output itself is very sensitive to scale changes (Moncada et al. 2016).

Valorization of transformation technologies is still a formidable hurdle facing the expansion of the nascent biorefinery industry, and productive integration of individual biorefinery conversion methods remains at a relatively early stage that will be discussed in Chap. 4.

By this scenario, the use of food waste-based feedstock, illustrated in Chap. 2, can pave the way to new and negative cost approaches to produce a greater variety of higher value end innovative products that will be discussed in Chap. 5, 6, and 7, along with more traditional outputs, which are the focus of interest of Chap. 3.

The current ongoing research in the hot area of biorefineries is therefore focused on developing an advanced model which can utilize a wide range of feedstocks, including food waste.

Bibliography

Alexandratos N, Bruinsma J (2012) World agriculture towards 2030/2050: the 2012 revision

Amaducci S, Facciotto G, Bergante S et al (2017) Biomass production and energy balance of herbaceous and woody crops on marginal soils in the Po Valley. GCB Bioenergy 9:31–45. https://doi.org/10.1111/gcbb.12341

Bren d'Amour C, Reitsma F, Baiocchi G et al (2017) Future urban land expansion and implications for global croplands. Proc Natl Acad Sci U S A 114:8939–8944. https://doi.org/10.1073/pnas.1606036114

Brundtland Commission (1987) Report of the world commission on environment and development: our common future towards sustainable development 2. Part II Common Challenges Population and Human Resources 4

Buffington J (2014) The economic potential of Brewer's spent grain (BSG) as a biomass feedstock. Adv Chem Eng Sci 04:308–318. https://doi.org/10.4236/aces.2014.43034

Chisti Y (2013) Constraints to commercialization of algal fuels. J Biotechnol 167:201–214. https://doi.org/10.1016/J.JBIOTEC.2013.07.020

David C, Gutiérrez B, Lorena D et al (2017) A comprehensive review on the implementation of the biorefinery concept in biodiesel production plants. 15:691–703. https://doi.org/10.18331/BRJ2017.4.3.6

Eccles RG, Krzus MP (eds) (2012) One report. Wiley, Hoboken

EIA (2016) International Energy Outlook 2016: U.S. Energy Information Administration (EIA), Washington DC

Elkington J (1998) Cannibals with forks : the triple bottom line of 21st century business. New Society Publishers

European Parliament (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. EU, Brussels. Consolidated text available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705. Accessed 8th Mar 2021

European Commission (2019) Communication from the commission to the European parliament, the European Council, The Council, The European Economic and Social Committee and The Committee of The Regions, The European Green Deal. EU, Brussels, pp 1–24. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019DC0640. Accessed 7th Mar 2021

Grooten M, Almond REA (2018) Living planet report. 2018:41

Hassan SS, Williams GA, Jaiswal AK (2019a) Moving towards the second generation of lignocellulosic biorefineries in the EU: drivers, challenges, and opportunities. Renew Sust Energ Rev:590–599

Hassan SS, Williams GA, Jaiswal AK (2019b) Lignocellulosic biorefineries in Europe: current state and prospects. Trends Biotechnol 37:231–234. https://doi.org/10.1016/j.tibtech.2018.07.002

International Energy Agency (IEA) (2009) Task 42 Biorefinery: Bio based chemicals value added products from Biorefineries, pp 1–16

Kharisov BI, Kharissova OV, Máximo C et al (2019) Greener synthesis of chemical compounds and materials. https://doi.org/10.1098/rsos.191378

Kiser B (2016) Circular economy: getting the circulation going. Nature 531:443–446. https://doi.org/10.1038/531443a

Lieder M, Rashid A (2016) Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J Clean Prod 115:36–51. https://doi.org/10.1016/J.JCLEPRO.2015.12.042

Mata TM, Martins AA, Caetano NS (2010) Microalgae for biodiesel production and other applications: a review. Renew Sust Energ Rev 14:217–232. https://doi.org/10.1016/j.rser.2009.07.020

Mohr A, Raman S (2013) Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels. Energy Policy 63:114–122. https://doi.org/10.1016/J.ENPOL.2013.08.033

Moncada B J, Aristizábal M V, Cardona A CA (2016) Design strategies for sustainable biorefineries. Biochem Eng J 116:122–134. https://doi.org/10.1016/j.bej.2016.06.009

Panoutsou C, Bauen A, Böttcher H et al (2013) Biomass futures: an integrated approach for estimating the future contribution of biomass value chains to the European energy system and inform future policy formation. Biofuels Bioprod Biorefin 7:106–114. https://doi.org/10.1002/bbb.1367

Robert KW, Parris TM, Leiserowitz AA (2005) What is sustainable development? Goals, indicators, values, and practice. Environ Sci Policy Sustain Dev 47:8–21. https://doi.org/10.1080/00139157.2005.10524444

Sadh PK, Duhan S, Duhan JS (2018) Agro-industrial wastes and their utilization using solid state fermentation: a review. Bioresour Bioprocess 5:1. https://doi.org/10.1186/s40643-017-0187-z

Sheldon RA (2016) Green chemistry and resource efficiency: towards a green economy. Green Chem 18:3180–3183. https://doi.org/10.1039/C6GC90040B

Sroufe R (2018) Integrated management: how sustainability creates value for any business. Emerald Publishing

The European Parliament and the Council of the European Union (2009) Renewable energy directive 2009/28/EC OF. Off J Eur Union 1:32–38

Toivanen H, Novotny M (2017) The emergence of patent races in lignocellulosic biofuels, 2002–2015. Renew Sust Energ Rev 77:318–326. https://doi.org/10.1016/J.RSER.2017.03.089

Trivedi J, Aila M, Bangwal DP et al (2015) Algae based biorefinery—how to make sense? Renew Sust Energ Rev 47:295–307. https://doi.org/10.1016/j.rser.2015.03.052

UNEP, UNEP DTU Partnership (2021) Emissions Gap Report 2020. https://unepdtu.org/publications/emissions-gap-report-2020/

United Nations (1992) United Nations Sustainable Development, pp 254–266

United Nations (2015) Transforming our world: the 2030 agenda for sustainable development. https://sdgs.un.org/2030agenda

United Nations, Department of Economic and Social Affairs PD (2019) World population prospects. Highlights

van Dam J, Junginger M (2011) Striving to further harmonization of sustainability criteria for bioenergy in Europe: recommendations from a stakeholder questionnaire. Energy Policy 39:4051–4066

Waite M (2013) SURF framework for a sustainable economy. J Manag Sustain 3:25–40. https://doi.org/10.5539/jms.v3n4p25

World Health Organization (2016) Ambient air pollution: a global assessment of exposure and burden of disease. World Health Organanization, pp 1–131

Wu D (2016) Recycle technology for Potato Peel waste processing: a review. Procedia Environ Sci 31:103–107. https://doi.org/10.1016/j.proenv.2016.02.014

WWAP (2017) The United Nations world water development report 201. Wastewater -The Untapped Resource