Chapter 1
Circular Economy Based on Residue Valorization

To meet the population's demand for products and services, it is inevitable that industry will interact with the environment during the search for inputs and outputs in the production processes. With the globalization of the market, it is no longer efficient or sustainable for companies to employ linear economic models in which the fundamental idea is to extract raw material, transform it, and discard it at the end of its life cycle [1].

For industries to adopt new models, fundamental concepts of the laws of nature must be pursued; the natural cycle of materials is one of the foundations of the circular economy. The expression *circular economy* has been used since the 1970s. It is based on the concept of an economy being restorative and regenerative with continuous development based on natural preservation and reduction [2]. Circular economics seeks to link business in the form of a network when, a material is no longer, it can be reallocated within a company or may be shared with another organization or segment that can take advantage of it and thereby generate revenue streams [3].

The development of the circular economy requires the adoption of systems that tend to move away from the traditional modules of food production, energy, and water use, seeking integrative adoption of practices that increase the conversion and valuation of residues into products that add value. Furthermore, it seeks to reduce the use of natural resources and wastes generated in agrobusiness, livestock farming, and other industries [4].

The benefits of a circular production system are categorized as short term and long term. In most cases, the advantages of modifying a production process are more intense at the end; in the short term, these changes require social and cultural transformations within organizations. Because this is a system based on the natural cycle, enterprises that adopt it must internalize the fact that the regeneration of resources such as water and energy requires time and space [5]. The values added to the circular economy, in addition to sustainability, are based on environmental quality, economic prosperity, and social equity, based on amenity values, economic resources, sinks for residual flows and support for increasing life cycles; all these bases are intertwined (Fig. 1.1) [6].

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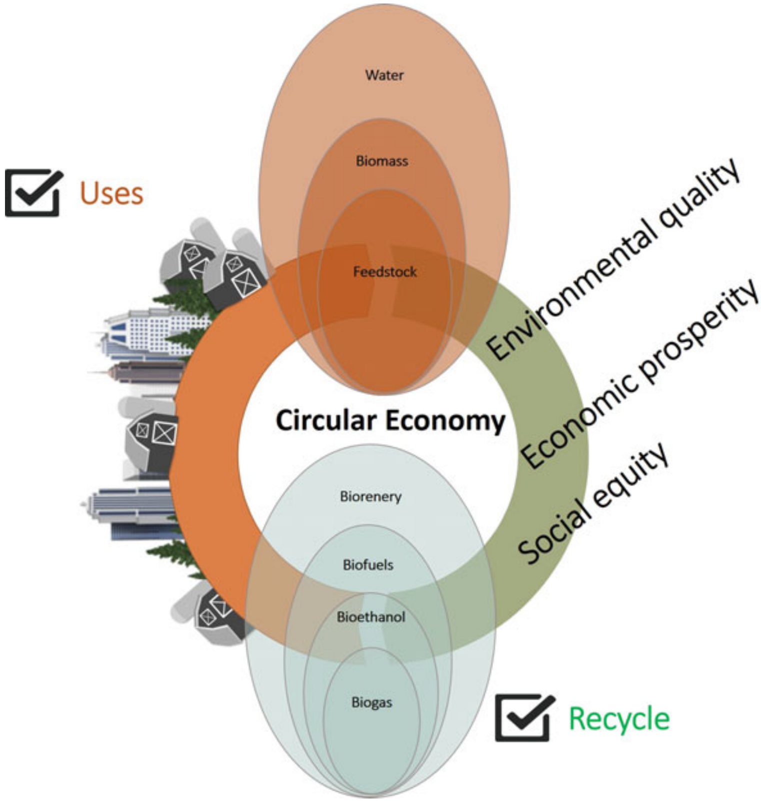

Fig. 1.1 Summary of the context of circular economy with an emphasis on biomass valorization. *Source* Authors

Many efforts have been made globally. The AgroCycle European program has sought to fully evaluate the capacity for recycling and valuation of agricultural waste to create new sustainable chains, accounting for the economic outlook [7, 8]. Worldwide, main products are identified using the circular chain approach and are used to valorize agro-industrial waste, mainly agriculture and livestock, for the production of biofuels, biofertilizers, water recycling, and reusable steam [9–11]. Residues such as lignocellulose derivatives and animal effluents are used for recovery of struvite, phosphorus [12], and noble metals [13] as well as serving as substrates for highly valued products [14, 15], including noble enzymes.

Throughout the last decade, the circular economy has become a doctrine for the agricultural, livestock, and agro-industrial sectors, using minimum inputs into the system to reduce costs and to close cycles of nutrients, water resources, and energy, reducing negative impacts to the biome, such as the emission of greenhouse gases and release of wastes. The circular economy will be more profitable with long-term implementation. Reuse and water recycling stand out among economic, social, and environmental strategies. The use of steam is an example because it is a by-product of several productive processes, permitting heat transfer and water recycling [16].

Reuse in agriculture and livestock is carried out in culture, animal supply, agro-industrial supply, and rural populations and is adopted to reduce the demand for drinking water. Water reuse is tied to its nutritional characteristics for fertilization and ferti-irrigation purposes. It is necessary to consider that, in these forms of water reuse, there is re-utilization of nutrients that augment growth and yield of crops because the wastewater contains large quantities of organic matter. Another source of recycling is bioenergy, using biogas and bioethanol, an emerging technology for valorization and optimization of biomass and water resources. Nevertheless, it is necessary to consider the need for control of bacterial, parasitic, and viral pathogens and toxic substances, such as heavy metals [16, 17].

Worldwide, biogas is generated mainly from food debris, animal waste, and human waste used for anaerobic digestion. Residues of livestock (poultry, cattle, and swine) have high energy potential for biogas, as do wastes from the sugar and alcohol industries, biodiesel production processes, dairy industry, citriculture, brewing, paper industries and pulp, urban solid waste, sewage treatment, and urban cleaning [18, 19].

In the production of first-generation ethanol (1G), sugarcane, corn, beets, and other cultivars are used. This practice has been widely debated, with a focus on environmental and socioeconomic problems associated with production processes and the need for exclusive cultivation of raw material affecting food demand, water security, and biodiversity. Second-generation and third-generation (2G and 3G) bioethanol focuses on the reuse of agricultural residues, such as, waste from the paper industry, glycerol, and by-products of the food industry [20]. It should be noted that, within the circular economy, ethanol production demands large amounts of water, requiring a reduction of the water footprint. There is a demand for water recirculation in the ethanol production chain and a constant emphasis on the reduction of freshwater use and its replacement by seawater, by wastewater and use algal biomass from treatment systems [21, 22].

It should be noted that the economic balance is essential for there to be interest and investment in new technologies based on the circular economy. The global energy appeal and cost–benefit pressures for such productions require efficient biotechnological methods with business models that are plausible for companies and industries in a company, business, or industry, focusing on reducing material flows and interconnected management [23].

The economic feasibility of reclaiming biomass lies precisely in the capacity to reuse goods and services and the use of biodiversity, microorganism technology, and recycled water resources. These processes are necessary to maintain environmental health and safety. The circular economy becomes a model largely based on ecosystems that produce energy, minimizing the impacts of waste [24].

In this sense, it is necessary to understand the biomass to be used with respect to its nutritional, structural, and molecular composition. These characteristics are essential to delineate the recycling of the biomass and the technology to be used, as well as its energy value. Advanced analytical methods are employed for structural and non-structural characterization of biomasses to be evaluated, using chromatography, mass spectrometry, electron microscopy, and X-ray diffraction (Chap. 2). Based on the characteristics of the biomass, it is necessary to choose pretreatments essential for the biomass to be bioavailable in conditions suitable for particular bioprocesses, such as biofuel production based on microbial activities. Within the concept of circularity and its economic aspects, it is emphasized that pretreatments (physical, chemical, biological, or combined) require investment in time and energy; this is the crucial step for the success of bioprocesses (Chap. 3). In addition, many inhibitory by-products can be generated that are inherent to pretreatments and detoxification processes (mainly employing enzymes) many of which are necessary to reduce inhibitory impacts (Chap. 4).

From this perspective, this book presents worldwide tendencies of productive sectors, focusing on agriculture, agroindustries, and livestock, in the ambit of economic circularity, because food producers and nutritional sources demand a great deal of natural resources, generating large amounts of waste that can be valorized by material engineering and biotechnological studies.

References

1. Murray A, Skene K, Haynes K (2017) The circular economy: an interdisciplinary exploration of the concept and application in a global context. J Bus Ethics 140:369–380. https://doi.org/10.1007/s10551-015-2693-2
2. Twigger HA (2016) Shifting perceptions: the reknit revolution. In: Centre for circular design circular transitions. University of the Arts of London, pp 57–67
3. Bonciu F (2014) The European Economy; From a linear to a circular economy. Rom J Eur Aff 14:78–91
4. Winkler MS, Krieger GR, Divall MJ, Singer BH, Utzinger J (2012) Health impact assessment of industrial development projects: a spatio-temporal visualization. Geospat Health 6:299–301. https://doi.org/10.4081/gh.2012.148
5. Park H-S, Behera SK (2014) Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks. J Clean Prod 64:478–485. https://doi.org/10.1016/j.jclepro.2013.08.032
6. Molina-Moreno V, Leyva-Díaz CJ, Llorens-Montes JF, Cortés-García JF (2017) Design of indicators of circular economy as instruments for the evaluation of sustainability and efficiency in wastewater from pig farming industry. Water 9
7. Toop TA, Ward S, Oldfield T, Hull M, Kirby ME, Theodorou MK (2017) AgroCycle—developing a circular economy in agriculture. Energy Procedia 123:76–80. https://doi.org/10.1016/j.egypro.2017.07.269
8. AgroCycle (2019) AgroCycle protocol rules 2019. http://www.agrocycle.eu/#project
9. Wang X, Yang G, Feng Y, Ren G, Han X (2012) Optimizing feeding composition and carbon–nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw. Bioresour Technol 120:78–83. https://doi.org/10.1016/j.biortech.2012.06.058
10. Guendouz J, Buffière P, Cacho J, Carrère M, Delgenes J-P (2010) Dry anaerobic digestion in batch mode: design and operation of a laboratory-scale, completely mixed reactor. Waste Manag 30:1768–1771. https://doi.org/10.1016/j.wasman.2009.12.024
11. Pawelczyk A (2005) EU policy and legislation on recycling of organic wastes to agriculture. International Society for Animal Hygiene

12. Liu Y, Kwag J-H, Kim J-H, Ra C (2011) Recovery of nitrogen and phosphorus by struvite crystallization from swine wastewater. Desalination 277:364–369. https://doi.org/10.1016/j.desal.2011.04.056
13. Fleming, C.A., Ferron CJ, Dreisinger DB, O'Kane PT (2000) A process for the simultaneous leaching and recovery of gold, platinum group metals and base metals from ores and concentrates. In: Taylor P (ed) EPD Proc TMS, Warrendale, 419–443
14. Venturin B, Frumi Camargo A, Scapini T, Mulinari J, Bonatto C, Bazoti S, Pereira Siqueira D, Maria Colla L, Alves SL, Paulo Bender J, Luís Radis Steinmetz R, Kunz A, Fongaro G, Treichel H (2018) Effect of pretreatments on corn stalk chemical properties for biogas production purposes. Bioresour Technol 266. https://doi.org/10.1016/j.biortech.2018.06.069
15. Sanchez S, Demain AL (2017) Chapter 1: Useful microbial enzymes—an introduction. In: Brahmachari G (ed) B of ME. Academic Press, pp 1–11
16. Shakir E, Zahraw Z, Al-Obaidy AHMJ (2017) Environmental and health risks associated with reuse of wastewater for irrigation. Egypt J Pet 26:95–102. https://doi.org/10.1016/j.ejpe.2016.01.003
17. Fongaro G, Viancelli A, Magri ME, Elmahdy EM, Biesus LL, Kich JD, Kunz A, Barardi CRM (2014) Utility of specific biomarkers to assess safety of swine manure for biofertilizing purposes. Sci Total Environ 479–480:277–283. https://doi.org/10.1016/j.scitotenv.2014.02.004
18. Guerini Filho M, Lumi M, Hasan C, Marder M, Leite LCS, Konrad O (2018) Energy recovery from wine sector wastes: a study about the biogas generation potential in a vineyard from Rio Grande do Sul, Brazil. Sustain Energy Technol Assess 29:44–49. https://doi.org/10.1016/j.seta.2018.06.006
19. Krzywika A, Szwaja S (2017) Putrid potatoes as biomass charge to an agricultural biomass-to-biogas power plant. Energy Procedia 118:40–45. https://doi.org/10.1016/j.egypro.2017.07.008
20. Neves PV, Pitarelo AP, Ramos LP (2016) Production of cellulosic ethanol from sugarcane bagasse by steam explosion: effect of extractives content, acid catalysis and different fermentation technologies. Bioresour Technol 208:184–194. https://doi.org/10.1016/j.biortech.2016.02.085
21. Milano J, Ong HC, Masjuki HH, Chong WT, Lam MK, Loh PK, Vellayan V (2016) Microalgae biofuels as an alternative to fossil fuel for power generation. Renew Sustain Energy Rev 58:180–197. https://doi.org/10.1016/j.rser.2015.12.150
22. Nizami AS, Rehan M, Waqas M, Naqvi M, Ouda OKM, Shahzad K, Miandad R, Khan MZ, Syamsiro M, Ismail IMI, Pant D (2017) Waste biorefineries: enabling circular economies in developing countries. Bioresour Technol 241:1101–1117. https://doi.org/10.1016/j.biortech.2017.05.097
23. Clift R, Allwood J (2011) Rethinking the economy. The Chemical Engineer
24. Pauli GA (2010) The blue economy 10 years, 100 innovations, 100 million jobs. Paradigm Publications, Taos, New Mexico