

15 Conclusions

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15.1 Introduction

In the following sections we explain how the book has answered the raised expectations for the main thematic issues introduced in the first chapter, such as circularity across established sectors, regional embedding and geographical context of waste valorisation, resource ownership and interfirm governance, and policy and regulations of waste valorisation. We also highlight possible future research perspectives for these themes.

15.2 Circularity across established sectors and sustainability of valorisation

The circularity and sustainability of valorisation of residues have been addressed on many occasions in this book. The sectoral case studies in **Part II** discuss circularity and sustainability of valorisation from different angles. **Chapter 4** compares examples of industrial symbiosis at different stages of maturity: the emerging valorisation of residues from the pulp and paper industry and aquaculture for producing liquified biogas and the diversification of value creation of a former pulp and paper company into an integrated biorefinery, exploiting wooden resources for producing chemicals, materials and food and feed ingredients, crossing the sectoral boundaries from forestry to chemical industry, food industry and feed industry. While in the first example two companies collocate and integrate their streams of residues, the second example shows how the integrated biorefinery evolved over time and created many collocated and connected activities addressing the valorisation of residues and side-streams. The company even specifically addressed the sustainability of its products and performed an LCA. In that way the company could exploit the whole feedstock and could become more energy efficient and sustainable. In **Chapter 6** a comparison of different options for the valorisation of brewers' spent grain shows that there are other options to gain more economic value out of this side-stream than just giving it away for free to local farmers, but that the sustainability of switching to such a pathway has to be carefully assessed when the use as feed for local husbandry is an

established practice and a lack of those feed resources would require the import of soya. The analysis of organic waste valorisation in land-based farming of salmon in **Chapter 8** shows that the salmon-producing companies are not driving innovation in this direction and they do little to assess the most sustainable use for the sludge from an LCA perspective. **Chapter 9** addresses valorisation of acid whey and explicitly reflects upon the sustainability of valorisation of side-streams. The authors stress that the valorisation of by-products has to also consider the context of traditional usage of those side-streams. Usage for human food or medicines may then be less sustainable than less technologically advanced solutions because the replacement of the established usage of side-stream by imports of feed from other continents might lead to more damage. The sustainability of valorisation pathways in terms of environmental, economic and social impacts has to be assessed through an LCA. Chapter 9 has also shown that new sustainability challenges can occur when the size of production increases.

The sectoral case studies have also shown that circularity and sustainable valorisation of residues are addressed differently in the private and the public realm. While in the public realm climate mitigation and sustainable development goals stand central, for companies the focus is on corporate social responsibility, and for that reason closed cycles and sustainable sourcing are addressed. For future research it would be important to address sustainable business models for the valorisation of residues and side-streams and how to compare the sustainability of different business models.

Part III showed us that quantitative studies can be an important source of insight into the bioeconomy, but that designing such studies is problematic and riddled with challenges. In **Chapter 10**, we learned that the CVs of researchers working on bioeconomy-focused research programmes under the Research Council of Norway can provide new insight into how knowledge production is organised in the bioeconomy and which knowledge bases are involved. A key finding in this chapter is that research on the bioeconomy is based on a wide range of disciplines, including agricultural and life sciences, engineering and the physical sciences, and social sciences, humanities and professional fields such as business administration and law. **Chapter 11** points out that the bioeconomy can also be studied using a wide range of different datasets such as R&D statistics, firm-level data and surveys. Nevertheless, all of these datasets have challenges related to defining the population of actors in the bioeconomy. Future research might study how the identified bioeconomy companies collaborate with firms outside their sectors and how careers of researchers are evolving through to collaboration with different types of companies.

Chapter 14 addresses LCAs as a tool for governance and, in this chapter, the difficulties in drawing the boundaries of an LCA are explained in more detail. They show that often LCAs are practised in a way that does not consider the circularity of the flow of resources properly but is based on an understanding which is dominated by a model of linear value chains.

Environmental impacts of recycling and reuse of resources can be studied either on an aggregated system level or at a more detailed level for the different products and processes of valorisation. When keeping the level of analysis at the aggregated level, many sustainability issues will become invisible and such analyses will not be useful for making the appropriate decisions. Therefore, future research avenues for addressing the circular and sustainable bioeconomy need to expand the scope of LCAs if they want to guide the governance of the bioeconomy.

15.3 Regional embedding and geographies of innovation

Geography is a recurrent theme in this book. **Chapter 4** explores how specific regional contexts affect the emergence of novel pathways for valorising forestry residues. In one of the Norwegian regions under analysis, in particular, forest-based value creation is reached by locating a biogas plant next to a pulp and paper plant, achieving a successful industrial symbiosis. The chapter also considers how regions can develop on the basis of their existing assets, including their endowment in terms of knowledge and institutions. Such a “path dependence” is theoretically framed in **Chapter 3**, together with the related concept of “lock-in”. The territorial embeddedness of institutions also emerges as a relevant element in value creation in **Chapter 8**, which suggests a socio-technical transition to valorise waste in salmon aquaculture through land-based farming. The same chapter also shows that the current distance between traditional coastal farming districts and inland waste processors may constitute a barrier to waste valorisation. A similar barrier is considered in **Chapter 7**, which describes how the small and scattered slaughterhouses in Norway face more difficulties in collecting and handling animal by-products in comparison to the fewer and much larger Danish slaughterhouses. **Chapter 10** shows, in contrast, how geographic boundaries of the national knowledge base can be overcome by establishing international consortia, who apply for funding in Norway through a bioeconomy-focused research programme. The political interactions across different spatial scales are explored in **Chapter 13**, where a multi-level governance framework is applied to analyse policy efforts for food waste reduction. Finally, **Chapter 14**, on life cycle analysis and governance, considers how political implications of life cycle thinking depend on the spatial boundaries imposed on the industrial systems under analysis.

The spatial boundaries considered for environmental systems vary depending on the specific problem to be solved. In some cases, the concentration of activities in a small area can constitute a problem, as in the case of coastal aquaculture mentioned above. In other cases, the spatial boundaries for the analysis must be extended to enclose the whole world, as in the case of the consequences of greenhouse gas emissions on global warming. In the latter case, municipalities and counties can be asked to face global challenges,

possibly with the intermediation of national state authorities. The connection between small-scale actions with large-scale challenges – “think global, act local”, as the motto goes – can translate into the multi-level types of governance necessary to achieve the coordination of different geographic areas towards common goals. Actors able to take the appropriate actions, in order to promote waste valorisation in the face of global challenges, can indeed often be found by authorities through a small-scale search: in this way, the authorities can determine the potential for small-scale regions to develop specific valorisation pathways. But private companies can also explore the possibility of detecting and following leading actors located in their own region: they could connect to, establish partnerships with and provide intermediate goods for innovative leading firms in the region which have already implemented valorisation processes. Many different types of relations can occur between firms at a municipal or regional scale. Input–output relations can be established within a region, to give rise to industrial symbiosis, or even to generate non-priced interactions for waste valorisation: the case of breweries giving spent grain free to local farmers may be an example. The extent and success of the interactions between regional actors will also depend on the institutional background of the region: formal and informal institutions will define whether new interactions are possible, and whether old interactions can serve new functions towards environmental goals. Moreover, the skill-base to which firms can resort when restructuring themselves towards waste valorisation may also be searched within their region: new valorisation pathways can then take place if the skills present in the region are sufficiently flexible to accommodate such evolution. However, competences not available at regional, or even at national, level can sometimes be reached by crossing national borders: R&D consortia may, for instance, help to create bridges towards different types of knowledge, while imports can contribute to the acquisition of foreign knowledge as embedded in machinery for waste transformation. Exports, on the other hand, can increase a firm’s market size, which in turn would translate into firm revenues, to be used for investments in side-stream valorisation.

Understanding how agreements on international trade affect the potential for waste valorisation, for the countries involved as well as for the world in general, constitutes an important line of future research. Tariffs, sanctions and other forms of trade restrictions have been shown, in this book, to have exerted a strong influence of the firms’ choices towards valorisation. The compliance with EU regulations is another international element that has been mentioned and could be the topic of further study, together with the alignment of national and regional policies with supranational decisions. In order to tune environmental policies according to the regions and sectors involved, further research should be devoted to studying the institutional idiosyncrasies of regions and sectors, bringing institutional theory insights deeper into economic geography and industrial organisation subjects. At the same time, LCA, enriched with social elements and with insights from

welfare economics, can stimulate researchers to define the correct spatial scale for answering questions on waste valorisation.

Research must explore the geographic dimension in order to define the opportunities for waste valorisation that are offered within specific regions or countries. Some geographic areas may indeed be more fertile for particular types of waste valorisation, in connection with particular economic sectors. Moreover, research can point to ways to overcome the limitations encountered in specific geographic areas, and show how economic actors, including firms and policymakers, can contribute to shaping new geographies of innovation which would favour waste valorisation.

15.4 Resource ownership and interfirm governance structures

In the introduction to this book, we suggested that the valorisation of waste streams often necessitates a high degree of coordination along and across value circles, but such coordination can be prevented by the intrinsic properties of waste. Indeed, both the amount and the production timing of waste depend on the needs of the value circle from which it originates, and are not usually planned on the basis of a potential waste valorisation. However, the book has shown several solutions that businesses can bring forward in order to avoid such a “waste puzzle”. Organisational solutions are, for instance, highlighted in **Chapters 7** and **9**, about the valorisation of, respectively, animal and dairy by-products. Both chapters witness the successful establishment, by a large firm dominant in the sector, of a subsidiary firm which would focus specifically on the valorisation of by-products. **Chapter 11**, on actors and innovators in the circular bioeconomy, confirms that firms who actively seek to realise value from organic waste streams often describe organic waste activities as core activities, which constitute a distinctive mark of the same firms. Moreover, **Chapter 6** shows the dangers of considering waste activities as peripheral to the firm: breweries would, for instance, focus on a new bottling line rather than upgrading their brewing equipment for a more efficient use of spent grain. Waste valorisation could come back into focus when a main product is branded according to the firm’s corporate social responsibility, as described in both **Chapters 3** and **6**. A firm’s environmental reputation may indeed exert a strong push towards waste valorisation: environmental groups are currently playing an important role in the context of salmon farming (**Chapter 8**), a role which could later be taken over by national governments. Better coordination between public and private actors, as well as within the public sector, could also lead to improved waste valorisation, as suggested by **Chapter 5** about the municipality’s management of urban waste in the city of Oslo. Within-firm coordination of different activities has instead been presented in **Chapter 4**, in the form of a Norwegian biorefinery which is able to optimise the cross-exploitation of side-streams from distinct firm activities.

If we put together results coming from the different sections of the book, two main suggestions can be brought to businesses. The first is based on incorporating waste valorisation explicitly in the firms' strategies. Without setting aside resources devoted to valorisation objectives, a firm will rarely improve the utilisation of current residues. By resources, we mean both human resources (for instance, in the form of R&D employees) and other physical resources (e.g. the equipment needed for waste transformation). Having one or more employees, within the firm, who explicitly take over the responsibility of waste valorisation, and get acquainted with themes that would not otherwise enter the firm's strategic discourse, can be an essential step. Waste valorisation may result from different technologies and can lead to different markets: expertise in this cannot be developed overnight, nor can the related subjects enter the firm's internal debates automatically. However, once expertise is developed within the firm, the subject is faced during regular meetings and investments take place as a consequence of long-term strategies, then waste valorisation can correspond to the promotion of the firm's main product: corporate social responsibility can become an element for product branding, and the firm itself can become an exemplary case in the eyes of environmental groups and national authorities, possibly helping to shape state regulations.

The second suggestion pertains to the cross-sectoral nature of waste valorisation. If a firm keeps a narrow view within its sectoral boundaries, it will rarely be exposed to the technical opportunities for waste transformation, or to the potential markets for future by-products. Keeping an innovative mindset within the firm, and letting incremental innovations shape the firm's development over time, would help to detect opportunities which sit outside the firm's comfort zone, and can lead to radical innovations in relation to new technologies and new markets. Once the opportunities have been explored, and cross-sectoral paths to waste valorisation have been established, the exploitation of those paths can be made stable by building organisational bridges between the sectors involved: for instance, entrepreneurs and managers from other sectors, who can have a specific interest in the waste valorisation processes of a firm, could be involved in the board or in the management of the same firm. Directorate interlinks or strategic partnerships could facilitate the connections needed for the valorisation of residues, and in particular contribute to ensure that resources can flow between sectors in a constant and efficient way. Such stability is often necessary to convince potential investors about the long-term profitability of waste valorisation.

To refine the two suggestions above, further research could proceed along two directions. First, it is important to understand whether agency within a firm can play a role in initiating processes of waste valorisation. While we can easily imagine firms reacting to changes in regulations, or in general reacting to traceable external impulses, it is more difficult to determine which forces can push a firm towards new valorisation pathways in the absence of a specific external impulse. Are there particular types of firms, and particular types

of firm organisations, which constitute a fertile ground where an employee's idea about waste valorisation can arise and develop? Systematic qualitative research on this subject could shed light on how to bring and keep side-streams within the set of a firm's core strategic resources. Second, a better understanding is needed of how inter-firm governance leads to waste valorisation. How do boards of directors change following waste valorisation strategies? Can we identify recurrent patterns in the evolution of senior management and of ownership, as coupled with intersectoral flows of side-streams? Given the usually public nature of data describing ownership and top management, quantitative analyses could provide precise answers to the questions above.

Different solutions may be adopted in accordance with different types of firm management and of industry structure. The fact that the valorisation of waste from a firm often requires coordination with other activities that do not normally pertain to the firm's industry makes it necessary to investigate specific types of innovation, and in particular of organisational innovation. Moreover, research is needed to understand how the new value assigned to waste can be recognised by markets and be translated into firm profits.

15.5 Policy and regulation of waste valorisation

To improve the sustainability and economic viability of the bioeconomy, policymakers should try to both *increase* and *improve* the use of organic waste streams. We have seen in this book that waste streams in many sectors are put to poor use from both an economic and sustainability perspective. In **Part II**, we have, in contrast, seen that most organic waste streams were put to some sort of use: urban food waste was incinerated or turned into biogas, acid whey and farmers' spent grain were used as animal feed and waste from on-shore aquaculture operations was used as fertiliser. Nevertheless, most of these waste streams could have been used more effectively still. Food waste could have been prevented or the food could have been reused, the acid whey and farmers' spent grain could have been used in the production of food additives and pharmaceuticals and the sludge from aquaculture could have been used to produce omega-3 fatty acids (see **Chapters 5, 6, 8 and 9**). These alternative applications have the potential for greater economic returns and improved sustainability. Policymakers should therefore focus as much on *improving* as on *increasing* the utilisation of organic waste. Nevertheless, policymakers should also be aware that achieving greater economic returns on some residual streams can result in uses that are less sustainable.

Policymakers should consider three main pitfalls when they attempt to govern and regulate the bioeconomy. First, they should be aware that lock-ins can easily arise from investments in organisational capabilities and physical infrastructure and prevent further improvements in sustainability. The case study on urban organic waste, in **Chapter 5**, illustrated how investments in physical infrastructure – such as optical sorting plants, biogas facilities and

incineration plants – required a steady flow of organic waste and provided little incentive for the municipality of Oslo to pursue more sustainable option, such as reuse or prevention of food waste. Second, they should be aware that regulations can have a strong effect on the innovative activity within a sector. In **Chapters 7 and 8**, we have seen that environmental and health and safety regulation influenced the innovative activity in the dairy and aquaculture sectors. The lesson is not that these types of regulations should be abolished. Rather, it is that these types of regulations should be implemented in a way that encourages rather than prevents innovation. Third, they should be aware that extensive outsourcing of services to private subcontractors can easily stifle innovation. In **Chapter 5**, we saw that the tender system the Oslo municipality used when it outsourced waste collection neither allowed for any mutual learning or exchange of knowledge between the private contractor and the municipality nor provided any incentives for the private contractor to improve the sustainability of the waste treatment system.

Policymakers should be aware that the bioeconomy consists of actors with varying and sometimes conflicting agendas. In **Chapter 2**, we learned that three different visions of the bioeconomy exist – a bio-technology, a bio-resource and a bio-ecology vision. We saw in **Chapter 12** that these three visions were represented by different groups of actors and that their different visions resulted in both conflicting and complementary interests and agendas. For policymakers it is important to note that if they try to introduce policies that run counter to one or more of these visions, they will meet considerable opposition. Conversely, if they can align these visions, they will receive support for their policies from the whole bioeconomy. Nevertheless, policymakers should be aware that regulating the bioeconomy will, in many cases, involve trade-offs between these visions and that they must balance the need for sustainability against demands for economic growth.

There are many interesting avenues for future research on policy and regulation of waste valorisation. There is a lack of systematic and comparative studies on how policymakers can increase and improve valorisation of waste, and studies that compare policies and regulations across different countries and across different waste resources should be very welcomed. Another interesting research avenue relates to how different actors try to influence waste valorisation policies. Do they attempt to form alliances with others of similar interests? Do they seek to affect policymakers through popular opinion or through concealed lobbying operations? Where and at what level are the most important policies developed – local, national or supranational?

15.6 Final remarks

This book has attempted to cover a broad range of issues related to the valorisation of organic residues and side-streams. It is situated within the wider scientific discourse about a circular and sustainable bioeconomy and tries to bridge different disciplinary approaches such as case studies, quantitative

data-driven analyses, LCAs and policy analysis. We are convinced that this approach has helped to increase the relevance of the book and the scientific soundness of its studies. A recurring topic in this book has been that valorisation of organic residues is not just about making more money out of waste, but also about improving sustainability and social cohesion. The sustainability of valorisation pathways must be carefully considered, and such consideration has to guide the actions of both private firms and public organisations in order to avoid lock-ins into unsustainable and ineffective solutions. Innovation will be needed for both public and private actors, according to a broadened view on valorisation possibilities which crosses sectoral, disciplinary and geographic borders.