



## A new circular business model typology for creating value from agro-waste

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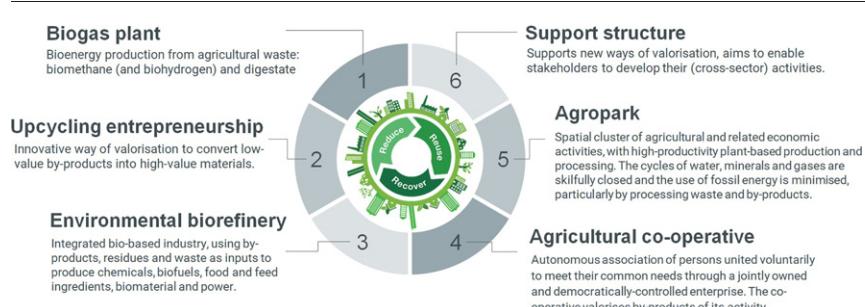
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### HIGHLIGHTS

- 39 business cases of agricultural waste and by-product valorisation are studied.
- A new circular business model typology is developed with six different types.
- The business model typology helps managers to enter new markets.
- The study contributes to a conceptual understanding of circular business models.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Shifting from a linear to a circular economy in the agri-food domain requires innovative business models, including reverse logistics, new visions on customer-supplier relationships, and new forms of organization and marketing strategies at the crossroads of various value chains.

This research aims to identify and characterise different types of business models that create value from agricultural waste and by-products via cascading or closing loops. Conceptual and management insights into circular business models are still sparse.

In total, 39 cases have been studied that convert agro-waste and by-products into valuable products via a circular economy approach. Semi-structured interviews and on-site visits of six representative cases have been done, and secondary data been collected. Data has been treated with content analysis. Cases are presented according to the type of organisational structure, resources, transformation processes, value propositions, key partners, customers, strategic approaches and innovation.

Six types of circular business models are identified and discussed: biogas plant, upcycling entrepreneurship, environmental biorefinery, agricultural cooperative, agropark and support structure. They differ in their way of value creation and organisational form, but strongly depend on partnerships and their capacity to respond to changing external conditions.

This study offers the first circular business model typology within the agricultural domain, revealing the interconnectedness of the six different business model types. It provides options for managers in positioning and adapting their business strategies. It highlights the potential of using biomass first for higher added-value products before exploiting it as energy source. Cascading biomass valorisation at a territorial level will increasingly be important for locally cooperating actors within a circular bioeconomy approach.

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## 1. Introduction

Our natural resources (energy, water, raw material) are limited and with a population estimated to reach 9 billion people in 2050, the current linear ‘take-make-dispose’ model is no longer sustainable (EMF, 2013). Based on the insight that today’s goods must be tomorrow’s resources, the Ellen MacArthur Foundation conceptualizes and defines circular economy as “an industrial system that is restorative or regenerative by intention and design” (EMF, 2015). Central to circular economy is the closed loop idea, aiming at enhancing the continuous flow of technical and biological materials in the value circle while keeping products, components and materials at their highest utility and value at all times and reducing waste to a minimum (EMF, 2013).

Circular economy is still an emerging concept (Velenturf et al., 2019) and in academic literature, there is neither yet a common theoretical framework nor consensus on a circular economy definition (Kirchherr et al., 2017). This is partly due to the fact that circular economy has emerged from policies and legislation rather than from academics (Murray et al., 2015). Another reason is that the concept has issued from different schools of thought with diverse theoretical and disciplinary backgrounds such as environmental economics, industrial ecology, performance economy etc. (Ghisellini et al., 2015). Some authors claim that the concept has first been introduced by the environmental economists Pearce and Turner (1990) in *Economics of Natural Resources and the Environment* (Andersen, 2007). There is a general agreement that circular economy, despite being a contemporary movement, is based on old ideas (Lewandowski, 2016). Until now, the relation between the concepts of sustainability, bioeconomy and circular economy are underexplored (D’Amato et al., 2017; Geissdoerfer et al., 2018; Millar et al., 2019).

The major challenge of implementing a circular economy is that it requires a change at a system level (Yuan et al., 2006; EMF, 2015), and an involvement of all actors within the value chains (suppliers, manufacturers, retailers, consumers). At an enterprise level, innovative business models are needed that replace existing ones or offer new market opportunities for new products (EMF, 2013; Bocken et al., 2016; Lewandowski, 2016). Teece (2010: 183) emphasises that “technological innovation by itself does not automatically guarantee business or economic success – far from it.” Therefore, professionals as well as scholars increasingly explore how new sustainable business models can increase economic growth while reducing negative effects on the natural environment and society (Bocken et al., 2014; Stubbs and Cocklin, 2008; Boons and Lüdeke-Freund, 2013; Schaltegger et al., 2016).

In this article, an empirical multiple case study with various business cases is done to identify and characterise different types of circular business models, and to get new conceptual and management insights into those business models applicable for the valorisation of agro-waste and by-products in a circular economy way. Advancing business models concepts and theory is important for describing and classifying businesses, for scientific investigation, and/or to develop practical recommendations and facilitate decision-making for managers (Baden-Fuller and Morgan, 2010; Taran et al., 2015). Until now, only few propositions have been made of how to categorize sustainable or circular business models (Lewandowski, 2016). The Ellen MacArthur Foundation (EMF, 2015) e.g. proposes the ReSOLVE framework which describes different circular business strategies: ‘regenerate, share, optimise, loop, virtualize, exchange’. Bocken et al. (2014) divide sustainable business models into eight archetypes which are classified in higher order groupings and describe the main type of business model innovation: technological, social or organisational. A recent review and classification of circular business model patterns has been carried out by Lüdeke-Freund et al. (2019). These authors base their study on a morphological analysis of 26 current cases from literature and identify six major circular economy business model patterns: (1) repair and maintenance, (2) reuse and redistribution, (3) refurbishment and remanufacturing,

(4) recycling, (5) cascading and repurposing, and (6) organic feedstock. These patterns correspond to the technical (1–4) and biological (5–6) reverse cycles of the famous circular economy butterfly diagram by the EMF (2015). Agro-waste and by-product valorisation concern biological cycles including cascading principles and organic feedstock conversion, but in this (sub)domain, a typology is still lacking. Such a typology is relevant, since the production of value-added products from specific agro-waste and by-products may not yet be economically feasible in many cases, mainly because of the low market prices of products, low quantities and seasonality, high transportation costs and water content (Bedoč et al., 2019). Hence, new insights in circular business models are requested and becoming even more important since the European Commission has adopted a circular, sustainable, bioeconomy strategy (EC, 2018).

## 2. Background: circular business models and agro-waste valorisation pathways

Since the 1990s, the interest in business models by professionals and academic scholars has rapidly been growing. While in the beginning, the concept was a buzzword of the internet boom (Magretta, 2002) and used by entrepreneurs within the new economy and e-commerce to propose new business ideas to potential investors (Chesbrough and Rosenbloom, 2002; Zott et al., 2011), later on, the business model was aimed to serve as tool for a structured analysis, planning, organization and implementation of enterprises (Geissdoerfer et al., 2018).

In its very basic and broad definition, a business model describes how a firm does business (Magretta, 2002). It refers to “the logic of a firm, the way it operates and how it creates value for its stakeholders” (Casadesus-Masanell and Ricart, 2010). It can be considered as a framework or architectural structure that describes the activities of a firm for creating and capturing value. A business model has not the same meaning as a business strategy. It is more generic than a strategy and not yet a guarantee for a unique competitive advantage of a firm, as business models can be copied (Teece, 2010). In order to be competitive, a business model must respond to particular customer needs and strongly be linked to the firm’s strategic analysis. It helps to translate the strategy into the firm’s activities, thus it enables to implement the strategy (Richardson, 2008). Casadesus-Masanell and Ricart (2010) emphasize that a competitive strategy of a firm precedes its model and defines the choice of a business model through which a company then competes in the markets.

Often, the business model structure is analysed according to the largely recognised Business Model Canvas of Osterwalder and Pigneur (2010). It consists of nine building blocks, where the value proposition – defined as the value proposed by an enterprise to solve customers’ problems and satisfy their needs – is central and linked to three business domains: (1) infrastructure, i.e. the key activities, partners and resources as strategic components, (2) customers, i.e. the customer relationships, the customer segments and channels as market components, and (3) financial components, i.e. the cost structure and revenue streams.

In order to shift from a linear to a circular economy and to integrate new technologies into new economic systems, innovative and disruptive business models are needed (Boons and Lüdeke-Freund, 2013; EMF, 2013). In the past years, an increasing number of publications on sustainable and circular business models has appeared (for an overview cf. Schaltegger et al., 2016). These two types are closely related and considered as a sub-category of business models (Antikainen and Valkokari, 2016).

Several definitions and frameworks of circular business models exist. For Mentink (2014: 35), a circular business model is “the rationale of how an organization creates, delivers and captures value with and within closed material loops”. Linder and Williander (2015: 2) define it as “a business model in which the conceptual logic for value creation is based on utilizing the economic value retained in products after use in

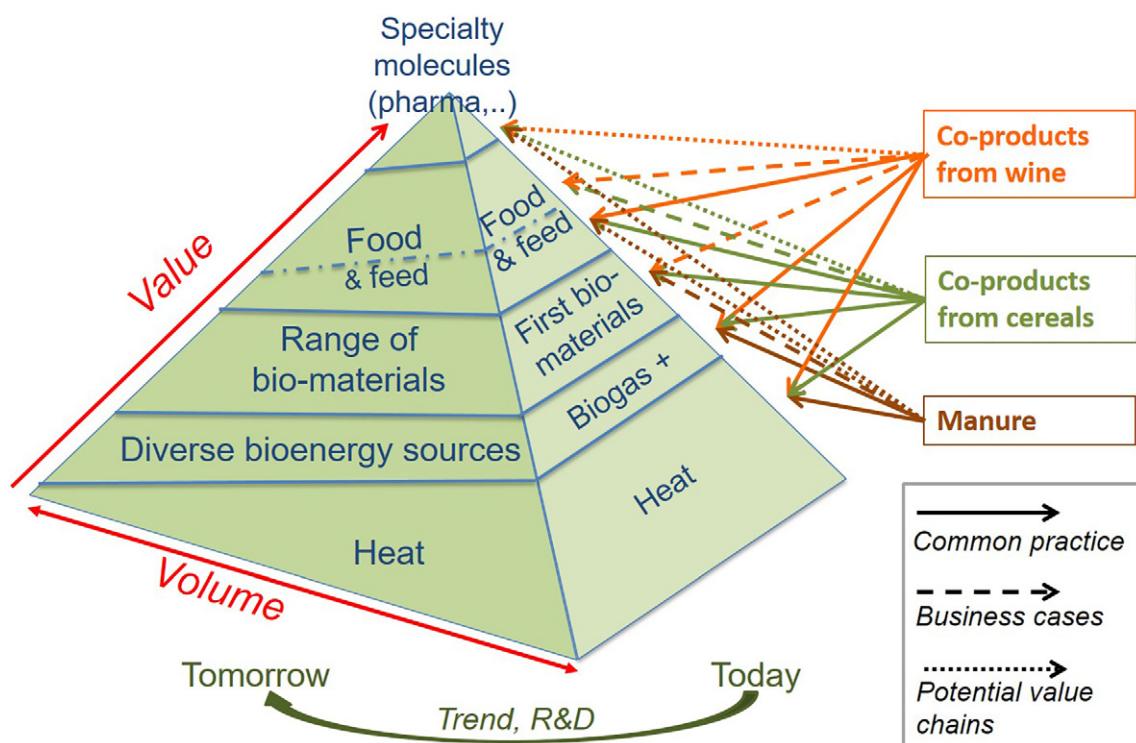
the production of new offerings". Micheaux and Aggeri (2016) differentiate a circular business model from a classical business model by its objective. Contrary to the classical model, the circular business model does not principally aim at economic performance, but rather at closing the energy and material loops, by ensuring a good financial health and thus, the long-term viability of the firm. Lewandowski (2016: 5) proposes a circular business model framework: he extends the business model canvas of Osterwalder and Pigneur by adding two more building blocks. The first one is a 'take-back system', including the idea of material loops where materials can be reused if collected back from the consumer or buyer; and the second one are 'adoption factors', assuming that a transition towards circular business models must be supported by various internal organisational capabilities and external factors. Finally, Antikainen and Valkokari (2016) offer a more extensive framework for sustainable circular business model innovation. Apart from the business level, which consists of the nine business model canvas building blocks, (i) the 'business ecosystem level' (referring to trends and drivers and to a stakeholder involvement having a direct impact on the business model) as well as (ii) the 'sustainability impact' (environmental, social and business requirements and benefits) are integrated in their framework. The idea is to come to a continuous sustainability and circularity evaluation of the business model within this framework, in order to understand and optimize the processes. In our study, the framework of Antikainen and Valkokari was adapted to the special context of agro-waste valorisation (Annex).

In this article, circular business models are meant to find innovative management solutions for the environmental challenge to use agricultural waste and by-products in a cyclical or cascading way, so that new products or applications can be developed based on natural resources (e.g. Mohan et al., 2016). Potential pathways for waste and by-product valorisation have been given especially from a chain perspective, like for cereals with an emphasis on characterisation, process intensification, down-scaling, intelligent steering and virtual designs (Elmekawy et al., 2013; Abecassis et al., 2014), for wine and wineries

stressing numerous options for platform fine chemicals, biomaterials, biofuels and fertilizers (IFV, 2013; Bordiga, 2015; Zacharof, 2017), for manure and agricultural residues upgrading digestates (Monlau et al., 2015). These new products should be affordable for consumers and target at a highest possible added value (Baiano, 2013), as indicated in the value pyramid (Fig. 1). Hence, there are different valorisation opportunities in alternative sectors leading to new products and applications, with a lower or higher value (Rood et al., 2017).

The challenges and opportunities for valorising agricultural waste and by-products have often been considered from a technological perspective (e.g. Bruins and Sanders, 2012; Barakat et al., 2013), but much less from a socio-economic one, and to our knowledge neither yet in the context of sustainable or circular business models nor in a typology of models.

Fig. 1 shows that often, value could be created via a cross-chain valorisation of agricultural by-products. This is specifically challenging due to the heterogeneity of resources, the changes in volumes and quality over time and regions, and the variety of conversion and end-user sectors (Federici et al., 2009). Moreover, by-product streams are mostly bulky; transport significantly impacts costs (Bedoic et al., 2019). Spatial clustering of different production chains is considered as one critical way for making such valorisations feasible, even though far from obvious (Smeets, 2011). The economic value of a chain's main product is still driving most business decision-making. From a marketing point of view, there is in general low awareness of valorisation opportunities in alternative sectors (clustered settings), and also consumers rather do not accept used or remanufactured products (Camacho-Otero et al., 2018). Finally, costs and benefits for agro-waste valorisation are not automatically allocated to the same party. Adequate business models are needed to create a setting where outcomes are just and fair for all parties. For effective use of agricultural by-products, both in terms of environmental benefits and added value, it is required to link innovative agricultural residues upgrading technologies and business opportunities by developing a cross-sectoral valorisation vision.



**Fig. 1.** Valorisation pathways of the main agro-waste and by-products researched in the EU-NOAW project with potential future value chain options.  
Source: own design

### 3. Methodology

The NoAW (No Agro-Waste) project,<sup>1</sup> financed by the European Commission, is driven by a 'near zero-waste' society requirement and focuses on the development of innovative approaches that allow the conversion of growing agricultural waste and by-products into eco-efficient bio-based products. In particular, co-products from wine, cereals and manure are addressed. Apart from the technological development aspects, one working package is dedicated to the challenge of how to design new business and marketing concepts for cross-sectoral valorisation of agricultural by-products.

Within this working package, a qualitative research approach has been defined, which is the dominant methodology for analysing business models so far, to explore them as current phenomena in their given contexts, as well as the antecedents and consequences of their configurations (Ehret et al., 2013). The case study method has been chosen, defined as "an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009: 18); this method is particularly appropriate for developing new theory and answering questions of why, what and how, while it allows better understanding of the nature and complexity of a phenomenon (Voss et al., 2002). Multiple cases have been studied, which augments the external validity (Voss et al., 2002).

Cases have been selected such that they fit into the following agreed scope: initiatives implying one or several actors more or less geographically close to each other and involved in agro-waste and by-product valorisation. The by-product valorisation relied either on a simple closing loop approach or on a cascade of valorisation pathways (bio-economy approach) implying many actors. From a technological point of view, special attention was given to initiatives implying by-product valorisation via anaerobic digestion.

In total, 39 cases of agricultural waste and by-product valorisation have been studied in 2016–2019, and that in 15 different countries or areas: Germany (5 cases), France (5), the Netherlands (4), Switzerland (3), Italy (2), Denmark (2), Norway (1), Sweden (1), Poland (1), Hungary (1), Austria (1), overall EU cases (2), Taiwan (8), USA (2), Vietnam and Brazil (1). For each of these 39 cases, a semi-structured interview has been done by members of the working package team following a questionnaire developed within the project. This questionnaire has been designed at the crossroads of macro-environmental political-legal (policies, laws, regulations) and economic (markets, subsidies) conditions, and micro-level business aspects such as historical (origin, triggers and development of the initiative), technological (type and maturity of technologies used, examples of by-product valorisation and outputs), organisational (governance, coordination, cooperation, logistics), financial (investments, cost-benefit structure), as well as environmental and social characteristics. The case-specific data from each interview has been resumed and presented in form of a one-page user-friendly factsheet. Data of all cases has been compiled in an excel file for a better comparability and analysed mainly regarding the types of initiatives, key valorisation pathways, and critical success factors and barriers.

Subsequently, six cases, from France, Germany, the Netherlands and Italy, have been selected out of the 39 international cases. These cases have been selected because they well represent six different types of circular business models for valorising agro-waste and by-products, and because they all are European cases, however facing different territorial contexts. Another reason to choose these business cases was the availability and openness of the managers to share more detailed information; it should be noted that three of them were project-partners. Consequently, the cases have been studied more in depth with on-site visits and semi-structured interviews. A detailed analytical framework

adapted to the bioeconomy context was developed ([Annex](#)), based on different sources: the business model framework proposed by Antikainen and Valkokari (2016), the analysis grid by Osterwalder and Pigneur (2010), and the Reseda (2017) methodology for analysing by-product valorisation pathways. It has been recommended in literature that a characterisation of business model types should include business model framework elements, such as customers, value proposition, organisational structure, economics and/or other value dimensions (Fielt, 2014). The interview questions thus addressed all the business model constructs of the framework, including the business ecosystem level, business level, and sustainability impact. Moreover, secondary data was collected through academic and online articles, websites as well as public and internal documents received from the companies. Interview and secondary data was transcribed followed by a content analysis (Berg, 2009). A hand-coding was done for each case to explore the main themes (within-case analysis). This was first done by one author and then verified and discussed with the other authors. The main points were then synthesized in the framework sheet for each case. In this article, the results per case are presented in [Table 1](#) below and highlight the main actor(s) involved, resources and transformation processes, value propositions, key partners, customers, strategic approaches and type of business model innovation. Next, the six cases have been compared again with the other 33 cases, in order to verify the insights gained and to uncover more general patterns and common characteristics of each circular business model category. Additionally, nine interviews with experts from different product chains and sectors (wine, cereals, manure) have been performed to verify whether critical issues had not been overlooked.

### 4. Results

The six cases differ in their way of value creation (focusing on different levels within the pyramid, [Fig. 1](#)) and/or in their organisational structure: (1) biogas plant, (2) upcycling entrepreneurship, (3) environmental biorefinery, (4) agricultural cooperative, (5) agropark and (6) support structure.

By comparing the results of these six in-depth case studies with the other 33 cases, individual specificities were rather neglected and common characteristics put forward for each circular business model category. In the following section, we highlight the main characteristics and value creation mechanisms of the six types of circular business models identified.

#### 4.1. Biogas plant

Farmers generate high amounts of agricultural by-products. Animal husbandry is one of the major agricultural activities in Europe; thus livestock manure represents a critical effluent to be valorised (Bolzonella et al., 2013). Therefore, many farmers have decided to develop anaerobic digestion processes to valorise their agro-waste. Both individual and collective initiatives exist. Joint infrastructures allow maximising the energy production, particularly due to mixing of complementary agricultural waste streams, and achieving economies of scale (Bioteau et al., 2013). To implement anaerobic digestion at farm level, the main challenge is to obtain funding for the technological investment. The value proposition consists of converting agricultural by-products into biogas, heat and digestate. The key activity is the management and optimisation of the entire biogas plant by trying to improve performance and reduce losses. Under-performance is likely to harm the project profitability. This point is crucial because it represents the main cause of biogas project failure (expert interview on 23 May 2018). Four types of revenue streams are identified: electricity, heat and digestate sales, and waste treatment services. If waste treatment services are envisaged as sources of income, an inventory of local available resources and a mapping of territorial energy demands are to be made. Here, Geographic Information Systems (GIS) are to be exploited (Bioteau et al.,

<sup>1</sup> <http://noaw2020.eu/>

**Table 1**

Six examples of circular business model cases for agro-waste valorisation.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Type of business model	Biogas plant	Upcycling entrepreneurship	Environmental refinery	Agricultural cooperative	Agropark	Support structure
Main actor(s)	Farmer with a biogas plant, linked to grid operator, e-car sharing firm, eco-village residents, farmers and wholesalers	University spin-off, collaborating with a large wine and cattle cooperative and two other universities	Eco-industrial cluster with various actors: several cereals and sugar cooperatives, food processing firms, a distribution company, several R&D centres, the regional government	Union of several wine distillery cooperatives whose members are smaller wine cooperatives and private wine farmers	Family business as founder serving as agropark manager; energy company, several logistic companies, a firm specialised in biodigestion, vegetable producers and data-centres	Local cluster of different stakeholders: a leading association, a small organic food industrial ecology park, a recycling enterprise, the local district
Value proposition	Biogas, electricity, fertiliser	Electricity, fertilizers, PHA for bio-materials	Plant proteins	Compost, ingredients for food & pharma industries	Heat, electricity	Biogas, network
Key partners	Local farmers	Cooperative, two other universities	Agrofood enterprises, research	Cooperatives and research Enterprises	Vegetable producers (greenhouses) and traders	Local authorities, enterprises and research
Customers	Public suppliers, private households (electricity), wholesaler (fertiliser)	Feed-in of electricity	Enterprises		Data-centres use electricity and produce heat for greenhouses	Local enterprises
Strategic approach	Enlarge product portfolio for mixed market sectors	Innovation, upscaling, pilot-scale demonstration, consultancy	New markets for large volumes of by-products	Innovation, mixed market sectors	Networking, economies of scale	Support for networking, niche strategy (organic)
Innovation type	Technical, social	Technical	Organisational, technical	Technical	Organisational	Social, organisational

2013). The bioenergy prices are fixed by national policies, and although the feed-in tariffs are in general still high in Europe, they are limited in running time and progressively decrease. The economic viability of this type of initiative is thus highly impacted by external political, legal and market factors. In Italy, subsidies for the production of biogas are 280 € per MWh for plants with a capacity less than 1 MW of electric energy; the running time is 15 first years (Bolzonella et al., 2013). In Germany, feed-in tariffs are guaranteed during the first 20 years of operation. Farmers with a biogas plant are thus obliged to further develop their business models with new customers, new distribution channels or product innovations and diversifications. In the German case e.g., the heat is sold to private households in the village, the electricity used for e-vehicles of a connected car-sharing association, and the digestate dried and converted into a marketable fertiliser for horticulture and viticulture. The collaboration with local authorities is imperative when heat and electricity are locally produced and used. The main stakeholders of the biogas plant business model type are the infrastructure supplier, the electricity, heat and digestate customers, farmers and local residents, in particular when noise and odor disturbances may create resistance. Main expectations are reliability, good quality and communication.

For biogas plant business models, the environmental benefits are mainly estimated through the number of tons of agro-waste valorised per year. However, Life Cycle Analysis shows that different factors have an impacting influence on the environmental benefits of the business: type of entrants (energy crops or others; Bolzonella et al., 2013), digestate spreading (expert interview on 23 May 2018), origin of raw materials and the conditions under which heat is valorised (firm interview on 6 June 2019).

#### 4.2. Upcycling entrepreneurship

Upcycling broadly describes the conversion of low-value by-products into high-value materials, in contrast to the maintenance of by-products as low value raw materials commonly transformed into material 'downcycling' practices (Oyenuga and Bhamidimarri, 2017). The upcycling concept has been increasingly recognised as a promising

way to reduce material and energy use (Sung, 2015). The upcycling entrepreneur develops an innovative way to convert low-value by-products into high-value materials. The entrepreneur starts his activity with one agro-waste stream, and develops a cross-sectoral application. There is a large diversity in the end-market applications (textile, construction material, furniture, gardening, food and drink etc.). The reason for this type of initiative lies in the necessity of finding a way to dispose of massive agricultural residues flows, or in a technological innovation which allows a new application. Both low-tech and high-tech approaches have been observed in our case studies. The development of upcycling entrepreneurship activities presents two main challenges. Firstly, the ability to scale up the process (Singh et al., 2019); after the validation of lab-scale process, solutions have to be found to convert agro-waste into end-products first at pilot-scale and finally at industrial scale. Secondly, the entrepreneur must secure continuous raw material supplies, meaning developing long-term partnerships with either farmers or agri-businesses to collect their by-products. For this type of companies, a major focus on the valorisation process and on eco-design was observed. The value capture strategy strongly depends on the context of production and commercialisation (especially BtoB vs BtoC marketing). A marketing challenge is to reach a positive consumer attitude towards upcycled products. Depending on the cultural context and the type of by-products used as entrants, consumers can be reluctant to buy waste-based products (Vincent and Marcoux, 2016). Prices adjusted to market prices of traditional substitution products represent a success factor (Singh et al., 2019). A majority of agro-waste-based products are defined as biodegradable. In one of the cases studied, biodegradable tableware is produced from wheat bran. This has two positive consequences: alignment with European legislation (Directive EU 2019/904) about single-use plastic tableware, and positive consumer attitudes to biodegradability, which represents a selling argument.

In this study, only SMEs and individual entrepreneurs were identified. Indeed, different barriers prevent large companies to develop upcycling activities (Sung, 2015): (1) possible trade-offs between the value and quality of currently accepted products and of potential products via upcycling in the future; (2) immature upcycling processes for various types and quantities of resources; (3) adapting collecting,

cleaning, sorting, drying, and homogenising steps; (4) inconsistent supply of resources with well-controlled quality in terms of composition and impurities and process complexity.

In terms of environmental impact, products issued from upcycling processes are seen as more sustainable since upcycling typically requires less energy than new products from virgin materials (Szaky, 2014).

#### 4.3. Environmental biorefinery

A biorefinery is an integrated bio-based industry, using a variety of technologies to produce marketable products (such as chemicals, biofuels, food and feed ingredients, biomaterials) and energy from biomass raw materials. A biorefinery aims at maximising the added value along three pillars of sustainability: environment, economy and society (Jong et al., 2009). The focus of this study was on environmental biorefineries, which only use agricultural by-products as inputs (Garcia-Bernet and Daboussi, 2016). The development of such an initiative is enabled by strategic collaborations between cross-sectoral partners within and outside the value chains. Public and private partners from the agricultural and end-product sectors need to be involved in this type of eco-industrial cluster. A biorefinery evolves in a territory with an economic, political and social identity; thus the success of a biorefinery project depends on the ability to create partnerships and to collaborate with a large panel of local players: farmers, agricultural cooperatives, industries, universities and research centres (Rakotovao et al., 2017).

In the biorefinery development process, different steps are observed: first, an industrial core group defines key valorisation pathways. Then, at R&D level, the process efficiency is maximised and technological innovations are revisited. Afterwards, a demonstrator is needed to scale-up processes from laboratory scale to an industrial scale (with the objective to cover all technology readiness levels and to be able to transform a concept into business opportunities). In the most developed biorefinery, two others levels can exist: an academic level (strong connections with a scientific community through multidisciplinary approaches) and a promotion level (Schieb et al., 2014).

The value proposition consists of maximising the added-value of the biomass and the resource efficiency. Since many of the higher added value compounds in the biomass residues are present in low amounts, their cost-effective exploitation requires the development of a combination of biomass cascading use being able to fully valorise all components (Odegard et al., 2012). The biorefinery realises subsequent use in time to enable a longer life span of the biomass (cascading in time). Some processes allow co-productions, i.e. the production of different functional streams from one biomass stream (cascading in function). The choice between alternatives is optimised to ensure that the highest value possible is achieved and the value over the whole life cycle is maximised (cascading in value).

To translate these principles into reality, the companies of the biorefinery deploy the following activities: agricultural resources collection, pre-treatment and fractionation steps, extraction and separation technologies, as well as physical, chemical and/or biochemical conversion, modification technologies, downstream processing and distribution activities. Based on the industrial ecology principles, a large number of mutualisation and substitution synergies are developed between the biorefinery activities. These synergies require strong connections between the involved players, both from a logistic and organisational point of view. Mutualized research and development (R&D) efforts are necessary for continuously improving the biomass exploitation processes (Gobert and Brullot, 2014). Key biorefinery issues are intellectual property rights, technology investments, expertise and competencies. These issues represent major financial resources for operating biorefineries.

The economic model benefits from economies of scale, diversification (the horizontal and vertical integration allow to exploit each

biomass constituent and maximise the value creation through offering large product ranges) and local know-how (Schieb et al., 2014). Revenue streams mainly come from the sales of products and services. The most promising market is currently the cosmetic sector, in which biorefineries face international competition. Customers are involved as stakeholders in the co-creation process and participate actively in R&D.

In terms of sustainability impact, the biorefinery enables replacing petro-based by bio-based resources. By developing valorisation pathways for by-products, farmers can benefit from an additional revenue stream. Biorefineries can also contribute to local development and employment in rural areas.

In Europe, two types of biorefineries can be identified: a traditional refinery shifting to bio-based activities; and an agropark or agricultural cooperative developing multiple valorisation activities and becoming a biorefinery. Our case study is part of the second category. Here, the role of farmers prevents them from destabilising local agricultural chains and from creating conflicts of use (e.g. with animal nutrition). Farmers focus on mobilising only locally available biomass.

#### 4.4. Agricultural cooperative

A cooperative is an autonomous association of persons voluntarily united to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise (International Co-operative Alliance, 2018). Agricultural cooperatives are usually created within a specific production sector (cereals, wine, fruits etc.). The production generates waste and by-product flows. Alone, one member has not the financial capacity to invest in a valorisation infrastructure, neither to gather a sufficient amount of by-products for making a valorisation pathway viable. However, a union of farmers in form of a cooperative is able to reach a critical size and to collect sufficient quantities of by-products (Coop de France, 2017). Co-operatives are interested in valorising their by-products for economic, regulatory or environmental reasons.

Cooperatives seek to establish long-term strategies in order to serve the members' interests durably. By mutualizing investments, cooperatives can fulfil a common need: converting member's by-products into marketable products. If internalized, this creates an opportunity to capture and share the value among members. In most of the cases studied, members of cooperatives did not have the professional background to manage a valorisation unit. At the beginning of a project, assistance from a specialised company or expert and training were needed. Cooperatives usually started with a low-value valorisation pathway (energy, alcohol or animal feed); and once first investments were successfully taken care off, they could consider high-value added valorisation pathways. This development strategy follows the different stages described by Beulque and Aggeri (2015) in their analysis of strategies of end-of-life businesses to generate value. In the first stage, the business model is based on systematically exploring market opportunities, while minimising social and economic implications. These business models are not diversified and focus on the most accessible product valorisation pathway with guaranteed market opportunities (e.g. high feed-in tariffs for biogas). During the second stage, businesses develop disruptive value creation strategies. Here, they pilot technical-economic feasibilities in order to multiply valorisation pathways and develop new end-products for new markets and customers' segments. The final stage is when the business reaches a high level of circularity through a strong partnership approach. The business then takes part of a broader business ecosystem, and actors cooperate with reciprocal prescriptions. Substantial investments are required and the business has to deal with high fixed costs.

Several cases of unions of cooperatives were studied in the wine sector in France. Historically, the main activity was the alcohol production, but now they obtain value via efficient cascading of wine pomace and lees into a large panel of products for various sectors (human and animal nutrition, cosmetic and nutraceutical industries). Their business

model reached the third step described by [Beulque and Aggeri \(2015\)](#) and shows similarities to the biorefinery concept, however is different as cooperative structure.

#### 4.5. Agropark

An agropark is a spatial cluster of agro-functions and related economic activities. It brings together natural resources-based production and processing along industrial principles. The cycles of water, minerals and gaseous compounds are skilfully closed and the use of fossil energy is minimised, particularly via waste and by-product processing ([Smeets, 2011](#)). An agropark aims to cluster companies in the direct environment of each other; this allows benefitting from joint waste management, natural resources usage and logistics. An agropark is based on the same principles as industrial symbiosis concepts, but it is dedicated to circular bio-based systems. Thus, one of the objectives is to optimize recycling, meaning re-utilization of waste from adjacent production and making the system as a whole more efficient and sustainable. While analysing different agroparks, some recurrent synergies became evident: a biogas plant makes it possible to valorise waste that can hardly be used in a higher-value recycling pathway. The electricity is used by the adjacent companies; the heat is either used for greenhouse heating and/or for aquaculture and/or drying of biomass. Aquaculture activities also benefit from by-products of food production serving as fish feed. The digestate left over from the biogas production serves as fertiliser. This nutrient recycling process supports crop growth. Some innovative cross-sector synergies also exist: in the Dutch case e.g. a large informatics platform is implemented in the agropark; the heat produced by the servers is used to heat greenhouses.

An agropark consists of various mutually dependent businesses thanks to a large number of synergies. This also evokes uncertainties with regard to technological, institutional and market development ([Ge et al., 2011](#)). One of the case studied illustrated this risk: when one company of the agropark has to stop its activities, all others companies are impacted and new solutions have to be found to ensure the continuity of businesses.

The concept of cluster theory is applicable to the agropark type of business model: the geographical proximity and concentration of the different actors that make up a cluster facilitates the synergies, but also encourages innovation in cleaner production and waste-management technology and the creation of new industries, particularly those that can use waste and by-products; overall, this finally leads to drive the local economy ([Montero et al., 2012](#)).

Furthermore, agroparks increase the mutualisation of know-how in production and commercialization of agro-products, and thus create a meeting place where actors from academia, entrepreneurs and industry come together to generate innovative ideas.

#### 4.6. Support structure

Contrary to the other types of circular business models identified, a support structure doesn't convert agro-waste into valuable products within its internal boundaries, but is part of a circular system which closes material loops through cooperation between different players ([Mentink, 2014](#)). Its value proposition is based on organisational innovation, and the activities are mainly based on coordination, networking, bringing together of normally disconnected players, technological and logistic intelligence and promotion.

Three types of support structures have been identified, with different approaches:

- Geographical approach: based on the industrial ecology concept, this type creates substitution and mutualisation between players within a well-defined territory. It ensures agropark coordination. Its missions may also include: raising stakeholders' awareness for sustainable development issues, providing support to local companies in

their environmental projects, federating local players and developing territory attractiveness.

- Valorisation pathway approach: this type of structure is created by organisations which want to develop an innovative valorisation pathway and decide to join their efforts. Together, they promote this activity and develop new markets and marketing strategies for their transformed by-products.
- Waste flow approach: the support structure helps farmers and agribusinesses to find the optimal valorisation pathways for their by-products. The starting point is to guarantee quality of the soil for farmers, hence asking for local recycling of essential nutrients. The remaining by-products can then be valorised. The support structure guides this process with both knowledge about soil quality, agronomy and new valorisation pathways.

Other sub-types of support structures (such as NGOs, consulting services, crowd-funding platform, incubators, etc.) also exist and provide opportunities for organisational innovation to valorise agro-waste ([Bocken et al., 2014](#)). In our study, no examples of such structures were identified.

Support structures are created to help companies in either a territory or a sector to develop their circular business models. These companies can be customers, partners or stakeholders of the support structure. Due to the heterogeneity of possible support structure business models, a precise description of each building block of the framework analysis cannot be given. However, some common features emerge: in most of the cases studied, support structures have difficulties in achieving a healthy financial balance. Some initiatives are created by means of public financial support but then, they fail in capturing economic value to ensure their long-term viability. Their economic model may include a remuneration for each synergy implemented or a financial support from targeted businesses for the services offered.

## 5. Discussion

In the past decade, the valorisation of agricultural waste and by-products has received quite some attention in research and academic literature from a product-technology point of view, revealing promising pathways (e.g. [Bruins and Sanders, 2012](#); [Barakat et al., 2013](#)). Also, optimum transport routes for agricultural waste and by-products have been researched. GIS mapping will be used to find a utilization in the current biorefineries, or in the planning of new biorefineries and local/regional intermediate processing facilities ([Bedoić et al., 2019](#)). This means focusing on the transition from Green to Sustainable Separation via holistic, flexible, and zero-waste biorefineries, integrating biomass, biofuel, biomaterials and bioenergy cycles ([Zuin and Ramin, 2018](#)). Now, there is a need to understand the business process of valorisation. Hence, new insights in business models and strategies for a circular economy are needed. Apparently, there is a lack of understanding how and under which conditions new products are entering the markets. Our analysis of circular business models, aiming at formulating relevant managerial recommendations for agro-waste and by-product valorisation, leads to three main discussion points: the specificities and internal management challenges of those circular business models, external factors impacting them, and the potential existence of an overarching circular business model typology.

With regard to the first, results of our study indicate that successfully implementing circular business models in the agricultural domain is in first instance a question of organisational and change management. Compared to business as usual, companies need to rethink and redefine their way of sourcing and supply, kind of partnerships and cooperation, and customer relationships. The waste and by-product collection constitutes a real challenge, as it implies costs and accounting-efficiency, creation of long-term partnerships with local farmers, quality

monitoring and handling perishability, seasonality and variability of agricultural products. Also, the transformation of low-value agricultural waste and by-products into marketable end-products requires specific value creation strategies such as biomass value cascading. In terms of commercialisation, fluctuating volumes of resources represent a constraint for markets who are traditionally not facing large fluctuations in product outputs (like chemical products) in terms of volumes and product specificities, hence research in logistics, storage and quality maintenance should be addressed. The perception of consumers of bio-based products is also often not known; perception may depend on knowledge of the origin of products, here co-products or waste, as well as on the sustainability profile of products, to name a few. Investing in customer education and behaviour studies is required.

Second, circular business models in the agricultural sector are facing common external challenges. The climate-change sensitivity is a major threat and may significantly impact the continuity of the business, in particular in specific regions. Increasing urbanisation (housing, education, commodities) has substantial influence on developing circular agri-business opportunities because rural areas may become overlooked and being less attractive for investments. The uncertainties about changing policies, laws and regulations also have a direct impact on the viability of valorisation pathways. This is particularly true in the biogas sector, in which gas purchase prices and subsidies are decreasing progressively; and in the biofuels sector as incorporation rates are not stabilized over time. Regulations and policies vary a lot between countries and make biogas production either more or less attractive. The impact in time of these external factors should be further investigated in future studies.

We recommend managers of biogas plants to look ahead and seek for new product and/or market opportunities well before subventions are reduced. This means consulting experts in creating value added co-products, potential new partners and customers. For upcycling entrepreneurs, it will be important to be strongly linked to technological research institutes, as well as to producers and marketers/clients to ensure the development of highly specialised products and a smooth flow of raw material supply and end product sales. Quite some potential technological developments are either still immature or require upscaling facilities. Biorefineries should also look for continuous technological developments, and maintain a good governance and transparent cooperation between the various actors involved; in addition, local supply of raw materials may soon become a limitation factor, thus extending the geographic circle of suppliers is recommended. Agricultural cooperatives however need to find a balance between their main production and by-product valorisation activities, while complying with the interests of its members; here, applying cascading principles or outsourcing certain activities can be a solution. From a marketing perspective, managers should take into account the perceptions of consumers that may be quite different for the various added-value products. For agroparks, we recommend to establish a continuous analysis of natural resources flows and logistics within the system in order to optimize the circularity; since the costs for competitive building grounds may substantially differ and evolve, continuous management attention is required. Finally, support structures could profit from communicating more strongly the importance of their intermediary role among public and private actors in order to guarantee their financial health and persistence. The number of niche areas, however, with very different support measures, may provide unique opportunities for future entrepreneurial managers.

Third, our typology includes six different types of circular business models, which raises the question of predominant types and their development. Our investigation permits to state that environmental biorefineries represent a new and highly adding-value form of an integrated business model, but only few examples currently exist. Potentially interesting valorisation pathways in bioeconomy require a better understanding of the functioning of biorefineries, especially in organisational terms (and not only technological) and in local contexts.

The biogas plant exists as business model since a few decades, but the regulation context (especially in terms of feed-in tariffs) has a high impact on the initiatives. As the subsidized feed-in tariffs last 20 years in Germany, biogas plants have rapidly been installed all over the country, however, actually they have to diversify and develop new revenue streams. Regarding the agropark type, closing-loop strategies are based on old agricultural principles, which were abandoned with the agriculture specialization and linear chain thinking, and are now revisited and adapted to the current context with new, interrelated actors. Agricultural cooperatives have initially been designed for production and mutualisation purposes, and not for valorising agro-waste and by-products; however, recent common ambitions to find pathways for by-product utilization both from an economic and an environmental perspective exist. Upcycling entrepreneurship is well known in developing countries (generally with a low-tech approach); it is difficult to actually evaluate its development in Europe. Finally, a high number of support structures has been identified. This type of business model could act as enabler to develop local circular projects or value chains via a leadership role, or as facilitator in cross chain connections and creation of new loops for products. However, despite their important role, support structures actually face difficulties in defining their economic model in the fast evolving circular economy.

The here proposed typology of six types of business models shows how circular business models differ in their organisational structure, their way of value creation and their embeddedness in the wider environment. The typology should not be considered as static. On the contrary, some business model types are at the intersection of two types, while others move from one type to another depending on changes in strategy and external conditions. The example of the wine cooperative clearly reveals a transition from a cooperative model to a small biorefinery via a cascading strategy for an efficient value creation of end-products. Other examples of agribusiness clusters are operating at the interface between the environmental biorefinery and the agropark type while seeking for strong synergies. The third example concerns a spin-off which has developed an innovative way the conversion of straw and manure into PHBV polymers; this type moved from an upcycling entrepreneurship towards a consultancy and networking enterprise specialised in technological innovation, hence becoming a support structure business model type in the bio-based PHBV sector.

Finally, the high number of cases studied, together with feedback from the expert interviews, confirm the robustness and the adequacy of the typology in this agricultural sector. Apparently, the different configurations tend to show self-organizing behaviour towards a limited number of business model types ([De Vries, 2017](#)). Even if some initiatives are at the intersection of two types or evolve from one type to another, they still belong to the overarching typology.

## 6. Conclusion

In this study, the diversity and characteristics of circular business models for valorising agro-waste and by-products have been shown, and an englobing dynamic typology been developed. Identifying the organisational forms and types of valorisation pathways highlights the potential of using biomass firstly for higher added-value products, before exploiting finally unused products as an energy source. Cascading biomass use plays a key role in the development of a circular economy, especially at territorial levels where clusters of SMEs and start-ups seek competitive advantages. Advanced and context-dependent circular business model concepts are important for understanding the value creation mechanisms and for facilitating decisions for managers to design appropriate economic models and market entry strategies. The here presented typology also serves as a classification tool to help investors and resource or equipment suppliers in understanding the current positioning as well as the short and long-term perspectives of the business. The inherent dynamic character of the typology allows actors to adapt their strategy in time and under changing contexts. It even may serve

to explore potential innovations and unsolved R&D issues, either as individual stakeholder or as member of a cluster.

The consequences for developing new management strategies are thus interesting to study in more detail. In circular business models, typical customer-supplier relationships are replaced by multi-actor relations in which the businesses are partly overlapping. This means that responsibilities are shared, e.g. a client is also co-responsible for the quality of products from its supplier because his output is partly used as input by its supplier (circular economy concept). The evolution of management schemes also implies shared strategies, co-creation of value and co-ownership, which leads to the question which activities will fully fall under internal management and which will be treated jointly. In case the complexity of clusters increases, e.g. via cross-sector activities, multiple players, diversity of resources, overlapping playing fields etc., the sharing of responsibilities will also become more complex. Hence, new priorities for management strategies should be defined which allow handling this complexity. Moreover, the management culture may need to change because the linear way of working facilitates management decisions – outputs are more or less linear, transparent and measurable – while the circular way of working leads to non-linear and, in general, unpredicted outcomes. Finally, social responsibilities and ethics are revisited because the management span of control – and hence all human resources related issues – becomes more extensive.

Until now, some publications (Bocken et al., 2014; EMF, 2015; Lüdeke-Freund et al., 2019) show how to conceptualize and categorize

sustainable or circular business models based on different strategies; they are presented as business model types in a wider context including environmental constraints. This study offers the first, consistent, circular business model typology with six different inter related business model types in the agricultural domain. This provides the opportunity to research its relevance for the wider sustainable and circular bioeconomy in the near future.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Annex. Framework for circular business model analysis (adapted from Antikainen and Valkokari, 2016)

Business ecosystem level	<b>Trends and drivers – PESTLE</b> Political: political incentives, local projects Economic: price of substitution products, raw materials, markets Social: consumer awareness and education, fashions and trends <b>Stakeholders involvement</b> Stakeholders' and interest groups' involvement and concerns (especially olfactory pollution, noise pollution, impact on real estate for neighbourhood) Network of players, clusters				
	Technological: innovation maturity, R&D, technology transfer Legal : legislation, law, standards Environmental : seasonality, sector environmental impacts				
Business level	<b>Key partners</b> Interests of by-products suppliers Long-standing partnerships Quality of partnerships Research partners Public partners Logistics partners Sharing infrastructure or other resources mutualisation Co-creation	<b>Key activities</b> Logistics Processing Valorisation process Quality and performance Insourcing/outsourcing choices <b>Key resources</b> Human resources Intellectual resources Technological resources Seasonality and variability Quality and predictability <b>Costs</b> Cost predictability Economies of scale Technology investment R&D investment – Return on investment	<b>Value proposition</b> Problem solved by the value proposition High value / low value products Differentiation from competitors Value chain modelling (cascading valorisation, inner loops, cogeneration, ...) Degree of innovation	<b>Customer relationship</b> Brand strength Costs for supplier change Solidity of relationships Consumer information et sensitisation <b>Channels</b> Distribution channels Communication channels <b>+ Reverse logistics</b> <b>Revenue streams</b> Price strategy – Price acceptance – Willingness to pay Profit margin Income diversification Financial subsidies	<b>Customers segment</b> B to B / B to C Customer segmentation Customer acquisition Attrition rate Conscious clients Consumer confidence in products
	<b>Sustainability requirements</b> National/local laws and regulations (water agency, ...) Stakeholders' requirement Continuous improvements Complementarity of resource use and consistency between players (territory + chains) - vs use conflicts				
Sustainability impact	<b>Sustainability benefits</b> Environmental: biomass valorisation efficiency, eco-design, ultimate waste, impacts on environment (soil quality, tonnes of waste avoid, eq. CO2, etc.) Social: number of jobs created, duration of employment Economic: turnover, persistence of activities Territorial: impact on territorial development, synergy with local players, territorial attractiveness				

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