Deliverable 2.1

Typology of intra- and cross-sectoral circularity initiatives

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WP2 Scoping and mapping the diversity and performance of cross-sectoral circularity

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Authors	Anda Adamsone-Fiskovica (BSC) With contribution by: Mikelis Grivins (BSC), Emils Kilis (BSC), Sandra Sumane (BSC), Talis Tisenkopfs (BSC), Oksana Zabko (BSC) Alberts Auzins (AREI), Ieva Leimane (AREI), Armands Veveris (AREI) Kristina Hiir (EMU), Kadi Kenk (EMU), Kristiina Kerge (EMU), Mait Kriipsalu (EMU), Rando Värnik (EMU) Jostein Brobakk (RURALIS), Pia Piroschka Otte (RURALIS) Aiste Bartkiene (VU), Renata Bikauskaite (VU), Diana Mincyte (VU), Ieva Sakelaite (VU)

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ABBREVIATIONS

AFA Agriculture, forestry and aquaculture
WP Work Package

1. Introduction

Deliverable 2.1 (Typology of intra- and cross-sectoral circularity initiatives) is based on the work carried out as part of WP2 (Scoping and mapping the diversity and performance of cross-sectoral circularity) and more specifically Task 2.1 (Mapping intra- and cross-sectoral circularity initiatives in the Baltic-Nordic region) and Task 2.2 (Building a taxonomy of intra- and cross-sectoral circularity initiatives and measurement).

Task 2.1 was devoted to the identification and characterisation of intra- and cross-sectoral circularity initiatives in the partner countries (Estonia, Latvia, Lithuania, Norway), based on their business practices, collaborative arrangements, sustainability impacts, digital tools used, and the bioresources involved to understand the state of circularity across and between agriculture, forestry, and aquaculture (AFA) in the Baltic-Nordic region. In line with an internally developed methodological guidelines, all partners identified 30 examples per country, amounting to a total number of 120 initiatives of various scales and forms described in a common structured form. These examples were gathered through various sources of information ranging from prior knowledge of team members to searches by relevant keywords in mass media as well as online resources. This material, in turn, served as an input to Task 2.2 with the aim of developing a typology of these different initiatives of circularity within the sectors and across sectoral boundaries (e. g. from agriculture to forestry and aquaculture).

While there are different categorisations of circular initiatives already available across different domains, the present attempt takes a specific focus on bioeconomy sectors of agriculture, forestry and aquaculture involving a wide diversity of valuable bioresources to arrive at a typology with underlying concepts that allow capturing specific aspects characterising the complex circularity of bioresources within and between the AFA sectors.

This report outlines a typology of intra- and cross-sectoral initiatives of a circular use of residual AFA bioresources built in the CIRCLE project. It provides a concise and structured overview of the initiatives within the identified types based on the information provided by partners from the four project countries according to a standard template, which has then been used as a basis for developing a categorisation of these initiatives based on selected (sectoral and organisational) dimensions of primary importance to the CIRCLE project. The next section briefly describes the methodology underlying data gathering and analysis. The subsequent section then lays out the underlying principles and categories of the proposed typology of intra- and cross-sectoral circularity initiatives of residual AFA bioresources, exemplifying the types by brief descriptions of the relevant examples from all countries. The report concludes with a summary of some of the main findings and points of discussion.

2. Methodology

While the entry point for the identification of the examples for the initial database was an individual company, the individual entries aimed to cover a specific flow of a single residual bioresource rather than whole loops of circularity implemented by the given company. Thus, a single company could serve as a basis for several entries in the database, each of which characterising a specific circular practice in terms of its technical solution, yet with additional information covering some basic features of the company as a whole. This approach in isolating single practices was chosen to allow for mapping the diversity of circularity solutions and the different flows of specific AFA-related residual bioresources within and across sectors and companies, rather than focusing on the underlying business models, which are to be explored in in-depth case studies (WP3).

The information provided in the common template among other items included the technical essence of circularity, specific residual bioresources involved, AFA sectors involved (incl. bridge sectors, if relevant), sectoral flow of the residual bioresource, the name and size of the company, status of the relevant business practice (business practice vs. business model), primary driving factors, customers of the product, type of collaborative arrangements, actors involved in the development and implementation of the circular solution, sustainability impacts, digital tools involved, energy used in the processes, regenerative practices applied, etc. Out of this breadth of information, **the unit of analysis chosen for the construction of the typology of intra- and cross-sectoral circularity initiatives was a specific residual AFA bioresource and its (1) sectoral flow and (2) organisational flow**. These two dimensions were chosen to form the basis of the typology due to their high relevance for the primary focus of the CIRCLE project – namely, collaboration for circular and sustainable use of residual bioresources, and the use of these resources in relation to the three designated bioeconomy sectors of agriculture, forestry and aquaculture.

Following the conceptual choice of these two dimensions and initial scanning of the database through these lenses, several iterations of the typology matrix were developed and piloted with a set of database entries to refine the type, number and definitions of subcategories for the two dimensions (as now elaborated in Section 3). When the typology dimensions and their categories were finally fixed, all the database entries were revisited one by one to categorise those along the types of the matrix and elaborate their concise descriptions to capture their essence and adherence to the specific type. After the preliminary distribution of the examples per type, specific requests were made to the partners in case some information was missing or needed to be clarified in order to make the final allocation of the example.

3. Categorisation of intra- and cross-sectoral circularity initiatives

To categorise the intra- and cross-sectoral circularity initiatives involving the use of a specific residual bioresource (incl. primary, secondary or tertiary)[1] either stemming from agriculture, forestry and/or aquaculture (AFA) or finding its further (unprocessed or processed) application in one of these designated sectors that were identified across the four countries, two key dimensions were selected (see Figure 1):

(1) **The sectoral flow of the residual AFA bioresource** – i. e. the nature of sectorality featured by this circular flow of the given residual AFA bioresource vis-à-vis the designated AFA sectors where:
   a. "intra-sectoral" stands for initiatives where the residual AFA bioresource both stems from and finds its application (either directly or through a bridge sector, such as energy) in the same sector (including its subsectors – e. g. crop production and animal husbandry in the case of agriculture);
   b. "cross-sectoral AFA" stands for initiatives where the residual AFA bioresource either stems from or finds its application in a different AFA sector, including those which return through being used/processed via a bridge sector;
   c. "cross-sectoral non-AFA" stands for initiatives where the residual AFA bioresource finds its application in a non-AFA sector.

[1] Elbersen, W., Schultze-Jena, A., van Berkum, S., Dengerink, J., Naranjo-Barrantes, M., Obeng, E. 2022. *Identifying and implementing circular applications of agri-residues: A circular evaluation framework for assessing impacts and circularity of different agri-residue applications*. Wageningen University & Research, pp. 14-15.

This axis describes the level of interconnections between individual AFA (and selected non-AFA) sectors either within or outside the observed organisational entity in the implementation of the circular use of a specific residual AFA bioresource.

(2) **The organisational flow of the residual AFA bioresource** – i. e. the nature of collaboration featured (or not) by this circular flow of the given residual AFA bioresource vis-à-vis the involved business entities (farms/companies) where:
   a. "intra-business" stands for initiatives where the residual AFA bioresource both stems from and finds its application in the same business entity;
   b. "inter-business" stands for initiatives where the residual AFA bioresource either stems from or finds its application in a different business entity.

This axis describes the level self-sufficiency of the arrangement within the observed organisational entity or (formal or informal) collaboration with other entities in the implementation of the circular use of a specific residual AFA bioresource.

Figure 1. Matrix of the typology of intra- and cross- sectoral circularity initiatives of residual AFA bioresources.

		SECTORAL flow of the residual bioresource		
		Intra-sectoral AFA	**Cross-sectoral AFA**	**Cross-sectoral non-AFA**
ORGANISATIONAL flow of the residual bioresource	**Intra-business**	**I** Self-sufficient sector-bound circular flow of a residual AFA bioresource	**II** Self-sufficient diversified circular flow of a residual AFA bioresource	**III** Self-sufficient extended circular flow of a residual AFA bioresource
	Inter-business	**IV** Collaborative sector-bound circular flow of a residual AFA bioresource	**V** Collaborative diversified circular flow of a residual AFA bioresource	**VI** Collaborative extended circular flow of a residual AFA bioresource

The intersection of the two dimensions accordingly results in six types of circularity initiatives that feature sector-bound, diversified or extended flows of residual AFA bioresources managed in either a self-sufficient or a collaborative way.

Below is a list of examples[2] per each of the six types featured by the typology focusing on the specific residual AFA bioresource used and its application, also highlighting the sector of the origin and destination for the given bioresource. Aside from the structured list of examples identified across the four countries, each type is provided with a condensed overview of the key properties of the type vis-à-vis the two selected criteria underlying the typology, along with a list of residual bioresources involved in the initiatives classified under the given type, as well as the use they are being put to and the intensity of sectoral coverage across the AFA triad.

[2] Due to more refined eligibility criteria the following examples from the database have not been classified as part of the typology: Latvia - LV01, LV14, LV15, LV19, LV20, LV28; Estonia - EE37, EE51, EE52; Norway - NO72, NO74, NO83, NO84, NO85, NO89; Lithuania - LT110, LT111.

Type I - Self-sufficient sector-bound circular flow of a residual AFA bioresource

This type of circularity initiatives [n=15(16)] represents arrangements of self-sufficient solutions implemented by individual business entities that make use of a specific residual AFA bioresource in their internal operations without any external input or supply to other entities (aside from that, which comes in addition to primary in-house use) and do so within the limits of a single AFA sector.

The residual bioresources used in these initiatives, generated by both primary production and on-farm processing, include cattle/sheep/chicken manure, sheep wool, by-products of slaughtered animals, fruit/vegetable/crop production leftovers, food waste, as well as on-farm pastures and specific locally grown varieties (used as alternatives for external inputs).

The application of these residual bioresources (either directly or through a bridging activity), in turn, include their function as fertilisers (incl. as compost) of cropland and pastures, livestock/chicken/fish feed, and source of bioenergy for on-farm use.

The sectoral coverage of these initiatives almost exclusively pertains to agriculture, as no examples in the given sample could be identified with regard to inter-sectoral circularity in forestry and only one in aquaculture. Yet, in the case of agriculture the examples feature variations in terms of circularity between sub-branches of crop production (incl. viticulture, horticulture) and animal husbandry, and vice versa, along with circularity within a specific sub-branch.

Technical essence of the bioresource flow	**Example ID[3] (company)**	**Sectoral bioresource flow**
Processing locally grown soybeans into livestock (pig) feed for in-house use	LV06 (farm "Rubuļi")	Agriculture (crop production) → Agriculture (animal husbandry)
Using own livestock manure for the production of biogas and, in turn, using digestate as fertiliser in crop production	LV09 (farm "Ziedi JP")	Agriculture (animal husbandry) → *(energy)* → Agriculture (crop production)
Using in-house sheep manure and residuals of sheep wool as fertilisers for own grapes	LV22 (farm "Marburkas")	Agriculture (animal husbandry) → Agriculture (viticulture)
Using own grape leaves as an in-house feed for sheep	LV22 (farm "Marburkas")	Agriculture (animal husbandry) → Agriculture (viticulture)
Using biogas from in-house agricultural residues for heating own glasshouses for seedlings and greens and using digestate as fertiliser	LV25 (farm "Mežacīruļi")	Agriculture → Agriculture (horticulture)
Using farm fish restaurant's food waste for own fish feed	LV26 (farm "Rideļu dzirnavas")	Aquaculture (+Agriculture) → Aquaculture
Undertaking in-house treatment of by-products from the slaughterhouse for the production of fertiliser	EE32 (HKScan AS)	Agriculture (animal husbandry) → Agriculture (crop production)

[3] The number denotes the ID of the example in the common Excel table, while the letters indicate the country where the example comes from (LV=Latvia, LT=Lithuania, EE=Estonia, NO=Norway).

Enriching soil with compost from own apple and vegetable production leftovers	EE44 (Loodussahver OÜ)	Agriculture (horticulture) → Agriculture (horticulture)
Using permaculture leftover vegetables for complementary chicken feed	EE50 (Telo Talu OÜ)	Agriculture (horticulture) → Agriculture (animal husbandry)
Using own pastures resulting from crop rotation as an in-house feed source for dairy cows	LT94 (Auga Group)	Agriculture (crop production) → Agriculture (animal husbandry)
Using cattle from organic dairy and beef production as naturally fertilisers of pastures, restoring nutrients for crop production	LT95 (Auga Group)	Agriculture (animal husbandry) → Agriculture (crop production)
Using waste resulting from animal husbandry for energy production for farming operations, including running hybrid biomethane and electric tractors	LT96 (Auga Group)	Agriculture (animal husbandry) → *(energy)* → Agriculture (crop production)
Using waste resulting from animal husbandry and agricultural production and food processing for organic feed	LT97 (Auga Group)	Agriculture (animal husbandry, crop production) → Agriculture (animal husbandry)
Using manure of free-range hens housed in mobile units as a natural fertiliser of pastures	LT98 (Auga Group)	Agriculture (animal husbandry) → Agriculture (crop production)
Producing biogas from processing agricultural products (primarily cereal-based) and using the resulting waste for production of fertiliser	LT119 & LT120 (Kurana)	Agriculture (crop production) → *(energy)* → Agriculture (crop production)

Type II - Self-sufficient diversified circular flow of a residual AFA bioresource

This type of circularity initiatives [n=4(5)] represent arrangements of less common self-sufficient solutions implemented by individual business entities that make use of a specific residual AFA bioresource in their internal operations without any external input or supply to other entities (aside from that, which comes in addition to primary in-house use) but do so across different AFA sectors.

The residual bioresources used in these initiatives from primary production include fishpond sludge and livestock manure.

The application of these residual bioresources (either directly or through a bridging activity of energy production), in turn, include their function as a fertiliser for orchards or as animal feed.

The sectoral coverage of these initiatives in the sample pertain to bioresource flow between agriculture and aquaculture.

Technical essence of the bioresource flow	**Example ID (company)**	**Sectoral bioresource flow**
Using own livestock manure for the production biogas and, in turn, using heat for fish farming	LV09 (farm "Ziedi JP")	Agriculture (animal husbandry) → *(energy)* → Aquaculture

Using sludge from on-farm fishponds as a fertiliser in the apple orchard	LV13 (farm "Lielkrūzes")	Aquaculture → Agriculture (horticulture)
Closed-loop fish farming integrated with agricultural production of vegetables	LT106 & LT107 (Noras LT)	Aquaculture → *(energy and compost)* → Agriculture (horticulture)
Using own livestock manure for the production of biogas for growing micro-algae as in-house animal feed	NO71 (Folven farm)	Agriculture (animal husbandry) → *(energy)* → Aquaculture & Agriculture (animal husbandry)

Type III - Self-sufficient extended circular flow of a residual AFA bioresource

This type of circularity initiatives [n=7] represent arrangements of self-sufficient solutions implemented by individual business entities that make in-house use of a specific residual AFA bioresource without any external input or supply (aside from that, which comes in addition to primary in-house use) to other entities but do so beyond the confines of AFA sectors.

The residual bioresources used in these initiatives include ones stemming from both primary production and processing such as plywood production, cider (apple) production, and slaughterhouse (e. g. intestines), as well as livestock/chicken manure, and biomass.

The application of these residual bioresources is mostly related to energy production for in-house use, which is not necessarily put to subsequent direct and exclusive use in ensuring primary production in AFA sectors but rather used for wider on-site energy needs (incl. heating of housing, powering of equipment).

The sectoral coverage of these initiatives in the sample predominantly pertain to bioresource flow from agriculture (covering both crop production and animal husbandry) to energy and food sectors, with only one example covering forestry.

Technical essence of the bioresource flow	**Example ID (company)**	**Sectoral bioresource flow**
Recycling chicken manure from own poultry houses in a biogas plant to produce electricity and heat for in-house use and sales	LV03 (Balticovo Ltd.)	Agriculture (animal husbandry) → Other (energy)
Making use of on-farm agricultural residues (manure, biomass) for the production of biogas for in-house use and sales	LV17 (Agrofirma Tērvete Ltd.)	Agriculture (animal husbandry and crop production) → Other (energy)
Undertaking in-house treatment of by-products from the on-site slaughterhouse (not suitable for other cost-effective uses) for the production of fuel for heating	EE32 (HKScan AS)	Agriculture (animal husbandry) → Other (energy)
Using residues from plywood production from own forests as a source of thermal energy for in-house use	EE36 (Estonian Plywood)	Forestry → Other (energy)
Using intestines from slaughtered livestock for in-house sausage production	EE45 (HKScan AS)	Agriculture (animal husbandry) → Other (food)

Using leftover apple pulp from on-site cider production for the production of smoothies	EE53 (Siidrikoda OÜ)	Agriculture (horticulture) → Other (food)
Using grain (wheat, buckwheat, corn) processing waste for production of briquettes used in drying pasta	LT118 (Ustukių Malūnas)	Agriculture (crop production) → *(energy)* → Other (food)

Type IV - Collaborative sector-bound circular flow of a residual AFA bioresource

This type of circularity initiatives [n=23(24)] represent arrangements of solutions implemented with engagement of several business entities either in the supply of input or use of output (where no further use of it is made internally) and where the use of a specific residual AFA bioresource is made within the limits of a single AFA sector.

The residual bioresources used in these initiatives include CO_2 resulting from animal husbandry, by-products from slaughterhouse, leftovers from vegetable production and grain (incl. buckwheat, wheat, barley, rapeseed)/ fruit/ potato/ herb processing, organic waste/biomass, digestate from processing chicken manure, livestock (cattle, pigs, horse)/ chicken manure, frass, sheep wool, fish waste, and wood ash.

The application of these residual bioresources is mostly related to their use in processed or unprocessed form for heating in agricultural production, animal/fish feed additive/ fodder, soil fertilisation (incl. through composting), mulching, and biological pest control.

The sectoral coverage of these initiatives in the sample is strongly dominated by agriculture with a lot of sub-sectoral flows of residual agricultural bioresources, yet there are also several examples from aquaculture, as well as one from forestry.

Technical essence of the bioresource flow	**Example ID (company)**	**Sectoral bioresource flow**
Processing residues of biogas (digestate) produced from own poultry manure to be sold as agricultural fertiliser	LV04 (Balticovo Ltd.)	Agriculture (animal husbandry) → *(energy)* → Agriculture (crop production)
Using livestock manure and biomass for the production of bio-humus (vermicompost) as an organic fertiliser	LV10 (Ekozeme Ltd.)	Agriculture (animal husbandry, crop production) → Agriculture (crop production)
Using by-products of rapeseed oil production in fodder production for sales	LV12 (Iecavnieks & Co Ltd.)	Agriculture (crop production) → Agriculture (animal husbandry)
Processing in-house green waste – organic residuals from plant and seedling production – into a compost subsequently used in commercialised mixes for use in garden and park cultivation	LV16 (Tree Nursery "Bulduri")	Agriculture (horticulture) → Agriculture (horticulture)
Using ash resulting from wood processing as a fertiliser in forestry	LV18 (Latgran Ltd.)	Forestry → Forestry
Using berry juice pressing residues as animal feed additives for sales	LV27 (Very Berry Ltd.)	Agriculture (horticulture) → Agriculture (animal husbandry)

Making use of potato residues from starch production in animal feed for sales	LV29 (Aloja Starkelsen Ltd.)	Agriculture (horticulture) → Agriculture (animal husbandry)
Using residues of cultivated and wild herbs used for essential oils production for the production of biological pest repellents	LV30 (Field and Forest Ltd.)	Agriculture (horticulture) → Agriculture (crop production)
Processing sheep wool into granules for soil fertilisation	EE31 (Villatoode OÜ)	Agriculture (animal husbandry) → Agriculture (horticulture)
Using grain (incl. barley) leftovers from a brewery as a sold feed additive in livestock farming	EE38 (Pühaste brewery)	Agriculture (crop production) → *(food industry)* → Agriculture (animal husbandry)
Using dirty sheep wool for soil enrichment and weed prevention on a neighbouring permaculture farm	EE40 (Telo Talu OÜ)	Agriculture (animal husbandry) → Agriculture (crop production)
Using by-products from fish industry to produce fish meal and oil for fish feed (and petfood)	EE41 (Eesti Kalatootjate Keskühistu TÜH (Paldiski kalakomponentide tehas))	Aquaculture → Aquaculture (+ Other)
Using digestate resulting from the biogas (biomethane) production from the residues of cattle farming (manure, slurry, silo) to produce solid and liquid fertiliser for sales	EE42 (Biometaan OÜ)	Agriculture (animal husbandry) → *(energy)* → Agriculture (crop production)
Using manure from a pig farm for soil fertilisation on local farms	EE48 (HKScan AS)	Agriculture (animal husbandry) → Agriculture (crop production)
Using peat mixed with chicken manure for soil fertilisation for local farmers	EE49 (HKScan AS)	Agriculture (animal husbandry) → Agriculture (crop production)
Selling in-house fish waste for the production of fish meal for use as animal (incl. fish) feed	EE54 (Liufish OÜ)	Aquaculture → Aquaculture (& Agriculture)
Using by-products from slaughterhouses and cutting plants, cassettes and dead animals for extraction of proteins for feed and fertilisers	NO75 (Biosirk Norway)	Agriculture (animal husbandry) → Agriculture (animal husbandry, crop production)
Using CO_2 from the adjacent dairy company to heat greenhouses	NO79 (Miljøgartneriet)	Agriculture (animal husbandry) → (*energy)* → Agriculture (horticulture)
Using waste from production of vegetables mixed with horse manure from neighbouring farms and then composted on site subsequently used in the vegetable production	NO90 (Skjergaarden)	Agriculture (horticulture, animal husbandry) → Agriculture (horticulture)
Using by-products of buckwheat processing for the production of fertiliser	LT100 (Ekofrisa)	Agriculture (crop production) → Agriculture (crop production)

Using by-products of buckwheat processing for the production of mulch	LT101 (Ekofrisa)	Agriculture (crop production) → Agriculture (crop production)
Processing frass resulting from insect (larvae) breeding into fertiliser	LT114 (Insectum)	Agriculture (insects) → Agriculture (crop production)
Grain product waste (e. g. broken wheat crackers) processed using specifications of partner companies and sold as animal feed supplement	LT116 & LT117 (Ustukių Malūnas)	Agriculture (crop production) → Agriculture (animal husbandry)

Type V - Collaborative diversified circular flow of a residual AFA bioresource

This type of circularity initiatives [n=17(19)] represent arrangements of solutions implemented with engagement of several business entities either in the supply of input or use of output (where no further use of it is made internally) and where the specific residual AFA bioresource flows across different AFA sectors.

The residual bioresources used in these initiatives include wood waste, forest fibre and wood ash, pine bark, fish waste, leftovers from grain (wheat, buckwheat, corn) processing, fishpond sediment/sludge, landfill biowaste, grass biomass, digestate, and livestock manure.

The application of these residual bioresources is mostly related to their use in a processed or unprocessed form for soil fertilisation and improvement (incl. composting), mulching, animal/fish feed, and greenhouse heating.

The sectoral coverage of these initiatives in the sample cuts across all three AFA sectors with forestry and aquaculture mostly featuring as the origin of residual bioresources, while agriculture dominating with regard to their application.

Technical essence of the bioresource flow	**Example ID (company)**	**Sectoral bioresource flow**
Using ash from burning wood bark and leftovers from cutting boards for drying pellets as a fertiliser in agriculture	LV02 (Stora Enso Ltd.)	Forestry → Agriculture (crop production)
Using pine bark as a by-product of the wood primary processing (peeling of logs) as a raw material for production of mulch for horticulture	LV05 (Aggregate Ltd.)	Forestry → Agriculture (horticulture)
Using collected biowaste in a landfill for biogas production for using electricity and heat to heat greenhouses	LV07 (Getliņi Eko)	Other (municipal biowaste) → Agriculture (horticulture)
Processing by-products from fishing industry (fishbones, skins, fat) as well as non-edible fish into fish meal and fish oil for usage as animal feed supplements	LV08 (Venta FM Ltd.)	Aquaculture → Agriculture (animal husbandry)
Using fish waste for compost production	EE55 (Pähkla Vähi- ja Kalakasvatus OÜ)	Aquaculture → Agriculture (horticulture)
Using fish waste for sales as animal feed for farms	EE58 (Võrtsukala OÜ)	Aquaculture → Agriculture (animal husbandry)

Processing food and agricultural waste for biogas, electricity and bio-fertiliser	LT91 & LT92 (Green Genius)	Agriculture & Other (biowaste) → Agriculture & Other (energy)
Processing sediment of fish farming operation into organic fertiliser for sales in agriculture	LT102 ((Bartžuvė) & LT103 (Šalčininkų žuvininkystės ūkis)	Aquaculture → Agriculture (horticulture)
Using sludge (food industry and fish processing and food waste (households, restaurants, food industry)) to produce methane gas and biodegradable fertiliser for agriculture	NO61 (ECOPRO)	Aquaculture & Other (biowaste) → *(energy)* → Agriculture
Composting collected biowaste to produce organic fertiliser, peat-free soil and biochar	NO63 (JordPro)	Other (biowaste) → Agriculture (horticulture)
Using animal manure and fish sludge for the production of bioenergy and bio-fertiliser	NO64 (RENEVO)	Agriculture & Aquaculture → *(energy)* → Agriculture
Using residuals from forestry and aquaculture (sludge) in the production of liquid biogas and bio-fertiliser	NO65 (Biokraft)	Forestry & Aquaculture → *(energy)* → Agriculture
Producing feed for salmon and livestock from forest fibre	NO66 (Foods of Norway)	Forestry → Agriculture & Aquaculture
Producing protein feed for salmon and livestock from grass biomass	NO67 (SusFeed)	Agriculture → Agriculture & Aquaculture
Production of biochar from forest and wood industry residuals for sales as a soil-improver and compost-improver for the agricultural and greenhouse sector, and as feed-additive	NO78 (Oplandske bioenergi)	Forestry → Agriculture (horticulture)
Producing biogas, bio-fertilisers and CO2 for the greenhouse sector from organic waste, livestock manure and sludge	NO80 (GREVE biogass)	Agriculture & Aquaculture & Other (biowaste) → (energy) → Agriculture
Conversion of low-quality biowaste from aquaculture, forestry and agriculture to feed substrates for crustaceans	NO81 (Biocycles)	Agriculture & Aquaculture & Forestry → Aquaculture

Type VI - Collaborative extended circular flow of a residual AFA bioresource

This type of circularity initiatives [n=32(33)] widely covered in the sample represent arrangements of solutions implemented with engagement of several business entities either in the supply of input or use of output (where no further use of it is made internally) and where the specific residual AFA bioresource flow goes beyond the AFA sectors.

The residual bioresources used in these initiatives include livestock skins, fat, bones and bowel epithelium from slaughtered animals, livestock manure, sheep wool, birch trees, birch bark, conifer greens, wood fibres, miscellaneous forestry residuals and wood waste, discarded vegetables, by-products of grain (wheat, buckwheat, corn) processing, fish waste, as well as miscellaneous organic/green waste and sludge (the latter two stemming from both AFA or non-AFA sectors).

The application of these residual bioresources is related to quite a diverse set of sectors to cover not only energy sector but also food sector, leather industry, chemical industry, pharmaceuticals, cosmetics, construction, packaging, and metal industry.

The sectoral coverage of these initiatives in the sample in terms of the AFA sectors covers all the three sectors with quite a few examples for residual bioresources stemming from each of these.

Technical essence of the bioresource flow	Example ID (company)	Sectoral bioresource flow
Using green waste from agricultural and wood industry for the residue-free production of liquid biofuels and biogas	LV11 (RTU Water Research and Environmental Biotechnology Laboratory, "Bio Re" Ltd.)	Agriculture (crop production) & Forestry → Other (energy)
Producing energy from forest residuals and wood waste in municipal heating	LV21 (Gren Jelgava Ltd.)	Forestry → Other (energy)
The use of conifer greens (pine-tree residuals) for building insulation	LV23 (RTU Institute of Energy Systems and Environment; Vecventa Ltd., Forma Ltd., ZARO Ltd.)	Forestry → Other (construction)
Production of betulin from birch bark for sales to pharmaceutical and cosmetic manufacturers	LV24 (Latvijas Finieris)	Forestry → Other (pharmaceuticals)
Using bowel epithelium obtained from slaughtered animals to be used in the production of bio-enzymes	EE33 (HKScan AS)	Agriculture (animal husbandry) → Other (pharmaceuticals)
Using dairy farm manure, slurry, silo to produce biomethane for use in the transport sector	EE34 (Biometaan OÜ)	Agriculture (animal husbandry) → Other (energy)
Using forestry residues for the production of heating pellets	EE35 (Graanul Invest AS)	Forestry → Other (energy)
Using by-products from the wood industry for making heating pellets	EE39 (Ardor OÜ)	Forestry → Other (energy)
Using sheep wool as a replacement of bubble wrap for packaging	EE43 (Woola OÜ)	Agriculture → Other (packaging)
Using skins from in-house slaughtered livestock for sales to textile / automotive industry	EE46 (HKScan AS)	Agriculture (animal husbandry) → Other (leather industry)
Using leftover fat from slaughtered animals for the production of lubricants	EE47 (HKScan AS)	Agriculture (animal husbandry) → *(food)* → Other (chemicals)
Growing chaga mushrooms on low quality birch trees for use in health elixirs	EE57 (Chaga OÜ)	Forestry → Other (pharmaceuticals)
Using fish waste (fish head, tail, skin, bones) for fish broth to be resold in retail shops and fish guts provided for dog-breeding companies	EE59 (OSAÜHING KARILATSI KALAMAJAND) &	Aquaculture → Other (Food, pet food)

	EE56 (Saare Kala Tootmine OÜ)	
Processing leftovers (bones, fat, skins) from free range livestock into pet food	EE60 (Muhu Liha TÜH)	Agriculture (animal husbandry) → *(food)* → Other (pet food)
Using food waste (households, restaurants, food industry) and sludge (food industry and fish processing) to produce biogas	NO62 (ECOGAS)	Agriculture/ Aquaculture/Other → Other (energy)
Production of vegetarian ready-made meals based on vegetables otherwise discarded	NO66 (Grønne Folk)	Agriculture → Other (food industry)
Utilising insects to efficiently process and upcycle locally available organic waste (industrial, catering and household) sourced from waste management companies into protein rich feed and food ingredients and fertiliser approved for organic farming	NO69 (Invertapro)	Other (biowaste) → Agriculture (animal husbandry / crop production)
Using wood fibres and organic waste to produce insect-based protein for food and feed	NO70 (Montasjen)	Forestry & Other (biowaste) → Agriculture & Aquaculture & Other (food)
Turning forest residuals and collected wood waste into new construction materials and source of energy	NO73 (SirkTRE)	Forestry → Other (construction, energy)
Production of bio-oil and biofuel from forest residuals	NO76 (Silva Green Fuel)	Forestry → Other (energy)
Replacing fossil coal with biocarbon (biochar) based on forest residuals as a reduction agent in the production-process of silicon and ferrosilicon	NO77 (Elkem)	Forestry → Other (metal industry)
Using livestock manure and aquaculture sludge for the production of biogas for transportation and industry	NO82 (Hardanger biogas)	Agriculture/aquaculture → Other (energy)
Production of biopolymer from wood (lignin) instead of fossil based, turned circular when using residuals from forestry	NO87 (Boregaard)	Forestry → Other (industrial applications, pharmaceuticals)
Production of bioethanol from wood, based on residuals from forestry	NO88 (Borregaard)	Forestry → Other (energy)
Processing sludge from municipal wastewater treatment into biogas/electricity and compost	LT93 (Vilniaus Vandenys)	Other (biowaste) → Agriculture & Other (energy)
Using by-products from buckwheat processing for the production of biogas for in-house use for powering the equipment and heating the plant	LT99 (Ekofrisa) & LT104 (Amilina-Roquette)	Agriculture (crop production) → Other (energy)
Fish farming operation (biowaste) integrated into biogas production and water supply system	LT105 (Žuvėja)	Aquaculture → Other (energy)
Using waste (sawdust and other by-products) from processing trees into lumber for bioenergy production	LT108 (Vigidas Pack)	Forestry → Other (energy)

Using waste from processing trees into lumber and other products in the production of furniture and building materials	LT109 (Vakarų medienos grupė (VMG Group))	Forestry → Other (furniture/construction)
Using food and other organic household waste for protein-rich insect (black soldier fly larvae) production for animal feed	LT112 & LT113 (Insectum)	Other (biowaste) → Agriculture (animal husbandry)
Using grain (wheat, buckwheat, corn) processing waste for production of briquettes used in drying pasta	LT118 (Ustukių Malūnas)	Agriculture (crop production) → *(energy)* → Other (food)

4. Conclusions

The proposed typology of circularity initiatives involving residual bioresources stemming from and/or finding their application in agriculture, forestry and aquaculture outlined in this report aims to capture the sectoral and organisational dimensions of the flow of these residual bioresources as featured by the rich set of examples gathered from companies operating in Latvia, Lithuania, Estonia and Norway.

While the initial database of examples amounted to 120 entries (30 per country), the number of those covered by the typology is 105 (condensed into 97 individual lines), as some, though enriching with regard to the overall topic circular use of bioresources, fell outside the scope of the dataset and subsequently also of this typology (e. g. due to focusing on sustainable but not necessarily circular solutions, moving too far in the supply chain away from primary production, or looking into the circular use of non-AFA resources in the AFA sectors). Nevertheless, in terms of the distribution of the examples included in the typology by country (see Figure 2), the overall balance has been retained, with country differences in coverage mostly featured in terms of the number of examples per type.

Figure 2. Number of examples of residual AFA bioresource circularity per country and type.

	Type I	Type II	Type III	Type IV	Type V	Type VI	TOTAL
Latvia	6	2	2	8	4	4	**26**
Estonia	3	0	4	8	2	10 (11)	**27 (28)**
Norway	0	1	0	3	9	10	**23**
Lithuania	6 (7)	1 (2)	1	4 (5)	2 (4)	7 (9)	**21 (28)**
TOTAL	**15 (16)**	**4 (5)**	**7**	**23 (24)**	**17 (19)**	**31 (34)**	**97 (105)**

Figure 3. Number of examples of residual AFA bioresource circularity per category and type.

		SECTORAL flow of the residual bioresource			
		Intra-sectoral AFA	**Cross-sectoral AFA**	**Cross-sectoral non-AFA**	**TOTAL**
ORGANISATIONAL flow of the residual bioresource	**Intra-business**	**I -** Self-sufficient sector-bound circular flow of a residual AFA bioresource	**II -**Self-sufficient diversified circular flow of a residual AFA bioresource	**III -** Self-sufficient extended circular flow of a residual AFA bioresource	**26 (28)**
		15 (16)	**4 (5)**	**7**	
	Inter-business	**IV -** Collaborative sector-bound circular flow of a residual AFA bioresource	**V -** Collaborative diversified circular flow of a residual AFA bioresource	**VI -** Collaborative extended circular flow of a residual AFA bioresource	**71 (77)**
		23 (24)	**17 (19)**	**31 (34)**	
	TOTAL	**38 (40)**	**21 (24)**	**38 (41)**	**97 (105)**

As can be observed from the list of examples per type, the distribution of the examples is not evenly spread across the six types (see Figure 3), with the bulk of examples (73%) concentrated in those that cover initiatives featuring collaborative inter-business relations in the given circularity arrangements (types IV, V and VI) and less in those that exemplify self-sufficiency of intra-business arrangements (types I, II and III). While this observation should not be treated as representative of the situation at large in the given countries and/or region, we see that inter-business collaborations are crucial for the development of circular value chains and circular economy since such collaborations allow pooling and adding value to residual bioresources and develop market for circular products.

The distribution of examples in the sample is more balanced with regard to the three categories along the sectoral dimension. Yet, if aggregating all cross-sectoral (AFA and non-AFA) examples, the sample has a smaller share of those that pertain to intra-sectoral flow of residual AFA bioresources (types I and IV). Again, this should not be treated as a representative characteristic of the field, as some more innovative cross-sectoral arrangements might be more visible in the public sources than ones that represent a traditional and less highlighted internal practice of many companies. At the same time, it should be noted that in the case of intra-business examples there are far more of intra-sectoral (type I) than cross-sectoral ones (types II and III), which does not come as a surprise as generally there are comparatively fewer companies that pursue their activities in more than one AFA sector and/or combine their AFA-sector related activities with in-house activities in non-AFA sector(s). In their turn, the collaborative arrangements generally allow for a much higher flexibility in terms of cross-sectorality (types V and VI) as companies can integrate their activities with those of others without the need of diversifying their own business.

In terms of the individual AFA sectors, the typology is dominated by examples coming from agriculture (especially due to the rich pool of residual bioresource flow possibilities between its sub-branches of animal husbandry and crop production), with far fewer examples featuring circularity arrangements involving forestry and aquaculture, especially between these two sectors. Yet, the ones that are featured in the sample do allow for capturing the potential of both intra-sectoral and cross-sectoral flows of residual bioresources within and between these AFA sectors and beyond, and show the creative circular uses different bioresources can be put to ranging from soil fertilisation, animal feed, weed and pest control, energy production, and production of novel foodstuffs, to wider applications in pharmaceuticals, cosmetics, construction, packaging, metal and leather industries.

The overall range of residual bioresources used in the identified initiatives in the case of agriculture include cattle/ sheep/ horse/ pig/ chicken manure and frass, sheep wool, by-products of slaughtered animals (skins, bones, fat, intestines, bowel epithelium), as well as residues of grain (buckwheat, wheat, rapeseed, barley) processing, discarded vegetables, leftovers from vegetable/ fruit/ potato/ herb processing, grass biomass, and organic/green waste more generally. Mention should also be made of food waste as well as landfill biowaste, which indirectly come from agriculture (and aquaculture), along with digestate that comes as a by-product of biogas production with input from agricultural residues. With regard to forestry, the residual bioresources for circular use originating from this sector are related to miscellaneous raw forestry residuals, including wood fibres, conifer greens, pine bark, birch bark as well as live birch trees, along with processing residues such as wood ash, wood waste from furniture production, by-products from plywood production, etc. In the case of aquaculture, the relevant residual bioresources mostly include fishpond sludge/sediment as well as fish waste (fishbones, skins, fat, non-edible fish). Some examples feature input of residual bioresources stemming from different sectors that are jointly put to the same further use (e. g. composting, biogas production, etc.), whereas in other examples diverse use is made of the same bioresource, incl.

application in both AFA and non-AFA sectors, thus revealing an additional layer of complexity in describing and categorising circularity solutions.

The overall review of the examples shows that there is quite a notable number of variations both in the way a single residual bioresource can be put to use and in the way its flow is organised within and/or between different sectors and companies. The pool of examples allows spotting the frequent role of bridge sectors (energy, in particular) that mediate the transformation of a residual bioresource in one AFA sector to a valuable resource in another. Likewise, it can also be observed that the flow between AFA and non-AFA sectors can be bidirectional with both residual AFA bioresources finding their application in non-AFA sectors and those from non-AFA sectors (e. g., biowaste coming from households, catering, water management) effectively used in AFA sectors. Of course, there are also many examples of making primary production more sustainable without involving circular use of residual bioresources (e. g. saving water, using residual heat, replacing external inputs with ones produced in-house), but these fall outside the scope of this typology that focuses specifically on circularity solutions.