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Potential of biomass sidestreams for a sustainable biobased economy

Bringing added value to agriculture and forest sectors by closing the research and innovation divide

AGRI FOR VALOR

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Preface

Modern society is dependent upon fossil-based resources that are cheap, abundant and available. Products of the fossil economy are of high quality and support nearly all aspects of society including transport fuel, energy production (e. g. solid fuel), food production (fertiliser), materials (plastic packaging, textiles), and chemicals (paints, glues, solvents, pharmaceuticals). However, fossil resources are finite and while one can argue about the length of time that fossil-based resources will continue to serve society they are not renewable. Furthermore, the use of fossil resources contributes to greenhouse gas emissions which contribute to climate change.

While a relatively new term in the world's lexicon, the bioeconomy, is ancient and has provided us with biobased products such as food, feed, biomaterials, chemicals, and energy for millennia. Extensive improvements in supply chains, extraction and separation efficiencies, conversion technologies, and product applications mean that many biobased value chains have been replaced by fossil value chains. The need to switch back to the use of renewable biobased resources is a great opportunity to apply modern thinking and technology to our natural resources and transition society towards sustainability. That switch is also intertwined with other sustainability challenges such as mitigating climate change, resource efficiency, food security, social fairness and others which are skillfully captured in the United Nations 17 sustainability goals. This adds additional layers of complexity to the switch from a fossil to a biobased economy.

The bioeconomy faces challenges that the fossil economy addresses daily e. g. resource heterogeneity, resource distribution, supply chains, resource efficiency and the production of high-quality and high value products. Which biobased value chains does one choose? "There is no one bioeconomy but multiple bioeconomies" (John Bell European Commission Head of Bioeconomy unit, Directorate General Research and innovation). Nations and regions will choose biobased value chains that play to regional strengths, but this smart specialization must be supported by high quality research data not only of

the region but also best practices and knowledge in other regions. Regional co-operation is a valuable way to enable this knowledge transfer in the bioeconomy that can create new jobs, contribute to rural regeneration and jobs close to the biomass.

The first iteration of the new emerging bioeconomy focused on bioenergy and liquid bio-fuels but thinking has evolved towards the production of higher value products such as chemicals and materials. However, society needs energy and so the cascading of biomass to first produce chemicals or materials followed by bioenergy production is needed. The need for large scale biorefineries was recognized over a decade ago ("Lead Market Initiative" (LMI) of the European Commission for biobased products taking biobased from promise to market 2008, doi 10.2769/34881) as being key to demonstrate the impact of biobased value chains. More of these are needed so that industry, policy makers and society at large can support the development of the bioeconomy for the benefit of their communities.

Farmers are central to the bioeconomy and yet there is a real risk that they will not be winners in the new bioeconomy value chains. Farmers need to re-organise so that they can maximise the value of their resource, not by bargaining for a better price for their feedstock, but by owning a share in the higher value biorefinery companies and products so they and their rural communities can greatly benefit from the bioeconomy. This will take some time to come about and will require co-ordinated education and policy measures to stimulate and reward innovation in agriculture, forestry and the marine. Smaller on-farm-biorefineries can enable farmers to engage early in the new bioeconomy. Farmers could convert their resource into higher value products (e. g. protein) on the farm, reduce transport costs, generate bioenergy (after cascading) for farm use, return nutrients to the soil (biobased fertilizer) as a result of small scale biorefinery side stream use, increasing resource efficiency and reducing dependency on fossil energy and fossil-based fertilizer. Larger ventures can occur in parallel or after the small scale biorefineries demonstrate their benefits. Inherent in these biorefineries is resource efficiency and circularity where side streams are used and waste minimized or avoided.

The bioeconomy is not just about harvesting and transforming our natural resources. It is also about inspirational natural capital that provides humans with a valuable recreational outlet that is also capturing carbon, improving air quality, and providing business opportunities for ecosystem services. The bioeconomy is full of biodiversity but also dependent upon biodiversity for resilience. Biodiversity can make the bioeconomy resilient by reducing our need for inputs such as water, fertilizer, pesticides, herbicides but also improve biomass productivity and soil quality.

The sustainable circular bioeconomy is a major challenge and opportunity that requires not only technological and ecosystem solutions but also strategic investment and policies that reward stakeholder innovation (including social entrepreneurship and ecosystem services). Co-operation between farmers, industry, technology developers, social scientists, business developers, policy makers, and wider society is critical to developing a holistic approach to developing a sustainable bioeconomy.

Dublin, February 2019
Professor Kevin O'Connor
Director BEACON SFI Bioeconomy Research Centre, Ireland
Chairperson Scientific Committee Biobased industries Joint Undertaking (BBIJU)

Editorial

Integrating farmers in bio-based value chains for a fair share of added value

The role of farmers, forest owners and their cooperatives is crucial for a successful transition to a European bioeconomy that contributes to rural development, circular economy and to tackling climate change.

It is always good to address future perspectives, but it is also important not to forget that the agriculture and forestry sectors have already carried out quite astonishing pragmatic initiatives to support and contribute to the uptake of bioeconomy, both in bioenergy and bio-based material production. Still, more could be done to better use the existing resources and increase the circularity of residues and by-products. This would require farmers and cooperatives to develop a kind of "natural instinct" by rethinking and internalising the concept of circularity. They need to propose proactive and concrete solutions together with upstream operators.

Better integration of farmers into bio-based value chains should also mean that farmers delivering raw materials receive a greater share of the added value. We need to continue to invest in agriculture and forestry, because a sustainable bio-based economy is not possible without sustainable farming practices. In this regard, paying attention to sustainability downstream is just as important as the work being done upstream. This is why the primary sector needs to get a fair share of the value added by bioeconomy. All local initiatives that have managed to scale up have one thing in common: a greater involvement of primary producers in the project and a fair income for their contribution.

As Copa and Cogeca, we also know that local willingness should be accompanied by strong policy support, at national and European level. Numerous initiatives promoting cooperation and a multi-actor approach have been implemented with national and EU support from the CAP (including EIP Agri), Horizon 2020 and the European Fund for Strategic Investments.

However, we still need a more strategic approach to bioeconomy if Europe wants to remain the front runner in line with the ambition expressed by Commission President Jean-Claude Juncker. This renewed vision should address the challenges that primary producers are facing – challenges such as the availability of and access to infrastructures, technologies and the logistics to increase biomass mobilisation and the availability of instruments to enhance their sustainability and competitiveness. The implementation of the EU Bioeconomy Strategy should reflect this by increasing the consistency between all EU policies and ensuring funding. Advisory services, knowledge exchange, investments, digitalisation, etc. should also be addressed as part of the implementation of the strategy.

Finally, we should also not forget that end consumers – in the food market, for example – will have a fundamental role to play by opting for bio-based products rather than non-renewable alternatives. Once again, the bioeconomy sector should rely on farmers to ensure the promotion of those alternatives. History shows that farmers and cooperatives across the EU can be trusted ambassadors and creative marketers.

Bioeconomy should be circular in all its dimensions, be it production methods, the share in added value or communication. Strong alliances between all relevant actors including consumers are necessary for a joint approach which addresses the sectors' needs for continued investment in sustainable bio-based solutions and in order to jointly promote the benefits that bioeconomy provides for the whole of society.

Brussels, June 2019
Oana Neagu, Director General Affairs
COPA and COGECA

Abstract

A sustainable and circular biobased economy is seen by many as a future base for a sustainable society and economy. In this sense bioeconomy and circular economy concepts must be systemically integrated.

The bio-economy is the key means to replace fossil fuels while ensuring a sustainable food production in order to cope with the global challenge of needing 50 % more food, 45 % more energy and 30 % more water in 2030 than today all at a time, when environmental boundaries are throwing up new limits to supply (United Nations secretary-General's high-level panel on Global sustainability 2012). The basic concept of a circular economy is a closed-loop system in which the final disposal of waste and by-products is minimised by promoting their reuse and valorisation (Corrado, Sala 2018).

New innovative techniques, partnerships, businesses and policies are being developed, replacing fossil based fuels and materials with renewable materials. Biomass, as renewable and abundant resource, has many direct and indirect applications for food, feed, fuels, fertilizers, chemicals and materials.

AGRIFORVALOR aims to close the research and innovation divide by connecting practitioners from agriculture and forestry to research and academia as well as with associations and clusters, bio-industry, policy makers, business support organisations, innovation agencies and technology transfer intermediaries in multi-actor innovation partnership networks. The focus of the project is on the transfer of know-how and information to enable and support farmers and foresters to exploit existing research results and facilitate the capture of grass root ideas for bio-industry development.

Practitioners addressed by the project are united in three Biomass Innovation Design hubs, piloted in Spain (Andalucía), Hungary and Ireland. In each of these hubs, existing research results and good practice cases on valorisation of biomass sidestreams from agriculture and forestry are shared and matched with the specific needs and potentials; new grass-roots ideas collected and devel-

oped; and dedicated innovation support applied to further deploy selected topics which are dealt with by multi-actor innovation partnership groups.

In the AGRIFORVALOR project an overview is drafted of valorisation techniques and good practice cases based on biomass sidestreams. Also, a web-based tool is developed, making this information easily available for stakeholders such as foresters, farmers, the biomass processing industries and the bioenergy sector.

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1 Biomass sidestreams for a sustainable biobased economy

The biobased economy is seen by many as a future base for a sustainable society and economy. New innovative techniques, partnerships, businesses and policies are being developed to support the biobased economy aiming to replace fossil based fuels and materials with renewable biobased materials. Biomass, as renewable and abundant resource, has many direct and indirect applications for food, feed, fuels, fertilizers, chemicals and materials. The type of biomass strongly differs per region. In the Mediterranean region a lot of olive and vine biomass is available, in Scandinavia it is mainly forest related biomass while in many other regions there is a lot of agricultural biomass production. However, biomass used for the biobased economy should not compete with food production. Therefore, especially biomass sidestreams are of interest for the biobased economy. Agricultural and forestry biomass sidestreams take the form of residual stalks, straw, leaves, roots, desk, nut or seed shells, animal husbandry waste, forest harvest residues, saw mill residues, etc. It is widely available, renewable, and cost-effective. Its use is carbon neutral, can displace fossil fuels, helps to reduce GHG emissions while closing the carbon cycle and it can be converted into a wide range of bioenergy and biomaterial products. When developing new routes for valorisation of biomass, it is important to take dimensions and criteria into account in terms of "people, planet and profit" in order to make the transition towards a sustainable future.

1.1 The AGRIFORVALOR project

AGRIFORVALOR aims to close the research and innovation divide by connecting practitioners from agriculture and forestry to research and academia as well as with associations and clusters, bio-industry, policy makers, business support organisations, innovation agencies and technology transfer intermediaries in multi-actor innovation partnership networks. The focus of the project is on the transfer of know-how and information to enable and support farmers

and foresters to exploit existing research results and facilitate the capture of grass-roots ideas for bio-industry development. This project was funded by the EC under H 2020 grant agreement number: 696394 from 2016–2018.

In the project, practitioners in the field of biomass sidestreams are united in three Biomass Innovation Design hubs, piloted in Spain (Andalucía), Hungary and Ireland. In each of these hubs, existing research results and good practice cases on valorisation of biomass sidestreams from agriculture and forest are shared and matched with the specific needs and potentials; new grass-roots ideas collected and developed; and dedicated innovation support applied to further deploy selected topics which are dealt with by multi-actor innovation partnership groups.

In literature and on the web, a vast number of research techniques and good practices can be found. To make this information more clear, the AGRIFORVALOR project drafted an overview of valorisation techniques and good practice cases and a web based tool making this information easily available for stakeholders such as foresters, farmers, the biomass processing industries and the bioenergy sector.

The AGRIFORVALOR project consortium is comprised of 16 partners from 6 countries:

Project Partner		Contact Person	Country
STEINBEIS 2i	**Steinbeis 2i GmbH**	Hartmut Welck	Germany
INSTITUTE OF TECHNOLOGY TRALEE INSTITIÚID TEICNEOLAÍOCHTA TRÁ LÍ	**Institute of Technology Tralee**	James Gaffey Helena McMahon	Ireland

UNIVERSITEIT GENT	**University of Gent**	Evelien Lambrecht	Belgium
WAGENINGEN UNIVERSITY & RESEARCH	**Wageningen University & Research, Environmental Research**	Kees Hendriks	Netherlands
Agencia Andaluza del Conocimiento CONSEJERÍA DE ECONOMÍA Y CONOCIMIENTO	**Agencia Andaluza del Conocimiento**	Cristina Cabeza	Spain
bay Bay Zoltán Nonprofit Ltd. for Applied Research	**Bay Zoltán Nonprofit Ltd. for Applied Research**	Katalin Kurucz	Hungary
growAbric	**GrowAbric**	Dr. Valéri Natanelov	Belgium
cooperativas agro-alimentarias Andalucía	**Cooperativas Agro-alimentarias de Andalucía**	Cesar Díaz Barroso	Spain
ASOCIACIÓN DE EMPRESAS FORESTALES Y PAISAJÍSTICAS DE ANDALUCÍA	**Association of Enterprises of Forest and Land-scape in Andalusia**	Javier Loscertales	Spain
Gabinete de Iniciativas Europeas	**Gabinete de Iniciativas Europeas (SME)**	Manuel Beltrán	Spain
teagasc Agriculture and Food Development Authority	**Teagasc's**	Barry Caslin	Ireland
IFA CELEBRATING 60 1955-2015	**Irish Farmers Association**	James Murphey	Ireland

	Irish Business and Enterprise Confederation	Mark McAuley	Ireland
	National Agricultural Research and Innovation Centre	Attila Benke	Hungary
	LAVINA Foundation for agricultural innovation	Dr. Nora Hatvani	Hungary
	PILZE Nagy Kft.	Dr. Adrienn Nagy	Hungary

Table 1: List of project partners and main contact persons (Source: EU funded project AGRIFORVALOR).

1.2 Andalusian Biomass Innovation Design Hub

The Andalusian hub is composed of the Andalusian Agency of Knowledge (AAC) (Hub Manager), with Federación Andaluza de Empresas Cooperativas Agrarias (CoopsAgroAND) as the main agricultural primary production partner, The Association of Enterprises of Forest and Landscape in Andalusia (AAEF) as the primary forestry representative and Gabinete de Iniciativas Europeas, S.A. (GIESA) as the main representative for the biobased industry.

AAC is a Public Agency under the Ministry of Economy and Knowledge of the Regional Government in Andalusia which fosters innovation among Andalusian entities, helping them to internationalize their innovations. AAC is WP 2 Leader and Central hub representative for Andalusia.

Federación Andaluza de Empresas Cooperativas Agrarias (CoopsAgroAND) Agrifood Cooperatives of Andalusia is a non-profit association comprised of 667 agricultural cooperatives in Andalusia, with the primary objective of advising them and representing their cooperatives and protecting their interests. Within AGRIFOVALOR CoopsAgroAND plays a key role in establishing networks, and facilitating knowledge transfer and dissemination within the agricultural sector.

The Association of Enterprises of Forest and Landscape in Andalusia (AAEF) is an employers' organization, created in 1989 to strengthen the forest sector in Andalusia. AAEF is central in communication activities within the hub and represents the forestry stakeholders.

Gabinete de Iniciativas Europeas, S.A. (GIESA) is an engineering and consultancy SME company located in Seville (Andalusia, Spain), with over 27 years of experience in the agri-food, environmental, biotechnology and bioenergy sectors. Within the Andalusian hub, GIESA represents the biobased industry sector and plays a specific role in disseminating biobased industry concepts.

1.3 Hungarian Biomass Innovation Design Hub

The Hungarian hub is composed of Bay Zoltan Non Profit Ltd. (Hub Manager), NARIC, Pilze-Nagy Ltd. and LAVINA Foundation.

Bay Zoltan Nonprofit Ltd. for Applied Research (BZN) is Hungary's largest and most successful public institution for applied research. Its mission is to support, in close cooperation with the private sector, the development of a sustainable competitive advantage for Hungarian companies through innovation services and technology transfer. The foremost objective of BZN is to provide state of the art solutions to its national and international partners. Bay Zoltan through their Department of Biology Based Energy Production has extensive experience in the valorisation of biological resources. BZN is the Hub Manager

within the AGRIFORVALOR Hungarian hub and is work package 3 leader focused on exploitation.

NARIC Forest Research Institute (NARIC FRI) participates in the project on behalf of the National Agricultural Research and Innovation Center (NARIC). NARIC FRI has over 100 years experience in research related to forest management and tree breeding. There are 91 people working at the Institute, 37 as researchers. NARIC holds close strong links with the forestry sector in Hungary, and supports the AGRIFORVALOR hub in establishing networks, promoting workshops, providing input to detect best practices, providing feedback on case studies, supporting know-how and innovation transfer as well as dissemination activities.

Pilze-Nagy Ltd is a family run medium sized enterprise which has been involved in the mushroom sector for more than 20 years. One of the core activities of Pilze-Nagy Ltd. is specialized waste management of agriwastes (spent oyster mushroom substrate) in its biogas plant. PILZE is a biobased industry representing the biobased industry sector in Hungary on the AGRIFORVALOR project with specific roles in identifying best practices, networking, communicating and disseminating biobased industry concepts. PILZE actively participates in the implementation of the project through its participation in workshops and events, through the provision of specific knowledge and support for the implementation of biomass innovation design hubs, and through its contribution to communication and dissemination activities.

LAVINA Foundation is a civil foundation for agricultural innovation and a non-profit applied research organization in Hungary. The Researching Department of Biotechnology (BIO) and Engineering Solutions (ENSO) at LAVINA has a long lasting cooperation with the academic and business sphere.

Within AGRIFORVALOR, LAVINA plays a role supporting the establishment of networks, promoting workshops, providing input to detect best practices and feedback on case studies, know-how and innovation transfer as well as supporting dissemination activities.

1.4 Irish Biomass Innovation Design Hub

The Irish hub is composed of Institute of Technology, Tralee (Hub Manager), Teagasc, Ibec and the Irish Farmers Assoication (IFA).

Institute of Technology Tralee (ITT) is a university level institution in Tralee, Ireland. Located in a peripheral agricultural region, the ITT is a centre of excellence in agricultural education and is home to a research community engaged predominantly in applied research developing solutions for enterprises regionally and nationally. ITT brings expertise in circular bioeconomy, biorefining and valorisation techniques as well as bioeconomy business model and enterprise development. ITT is the Work Package 4 leader for AGRIFORVALOR focusing on the development of new business models.

Teagasc is the national body providing integrated research, advisory and training services to agriculture and the food industry, employing 1,100 staff at 55 locations nationally. Teagasc supports the Irish hub in knowledge transfer, network development and dissemination to the agricultural and forestry sectors.

Ibec is the largest business representation organization in Ireland, representing the interests of 7,500 companies and organizations of all sizes and sectors. The Irish Forestry and Forest Products Association (IFFPA) is the branch of IBEC with special representation for the forestry and forest-based business sector in Ireland. IFFPA supports AgriForValor in network development, knowledge transfer and dissemination to the forest industry sector.

The Irish Farmers Association (IFA) is a national organization representing the interests of 88,000 members across all sectors of farming in Ireland. The IFA supports the Irish hub in network development, knowledge transfer and dissemination to the agricultural and forestry sectors.

1.5 Outline of the article

This article summarizes some practical information from the AGRIFOR-VALOR project and starts with an overview of available biomass sidestreams, with their possible valorising techniques and resulting outputs observed in the three studied hubs and Europe in general. Afterwards, we zoomed in on five good practice cases from both the agricultural and forestry subsectors. This is followed up by a presentation of the sidestream value tool, a web-based tool to share information, connect multi-actors and identify exploitation topics as well as support the development of grass-roots ideas to be further developed in new business models. Next, the article provides some relevant issues for regional business cases which are built up upon biomass sidestreams that are available in a large extent in the three regions. Issues discussed are the security of biomass supply, environmental issues, policy support and access to finance. Moreover, an outlook on sustainable circular Bioeconomy models is given and recommendations on hub and EU level and finally, conclusions are drawn, stressing the importance of connecting to multi-actor networks to access knowledge and business solutions.

2 Available biomass sidestreams and valorising techniques

For Europe (EU-27) available biomass sidestreams was estimated to be 314 MTOE, of which agricultural residues (89 MTOE) and round wood (57 + 41 MTOE) are the main sources (figure 1). In AGRIFORVALOR round wood production is not considered as sidestream. The price of this type of biomass is relatively high by which typical wood products (e. g. construction wood, furniture) are economically more profitable than energy or bio-based applications.

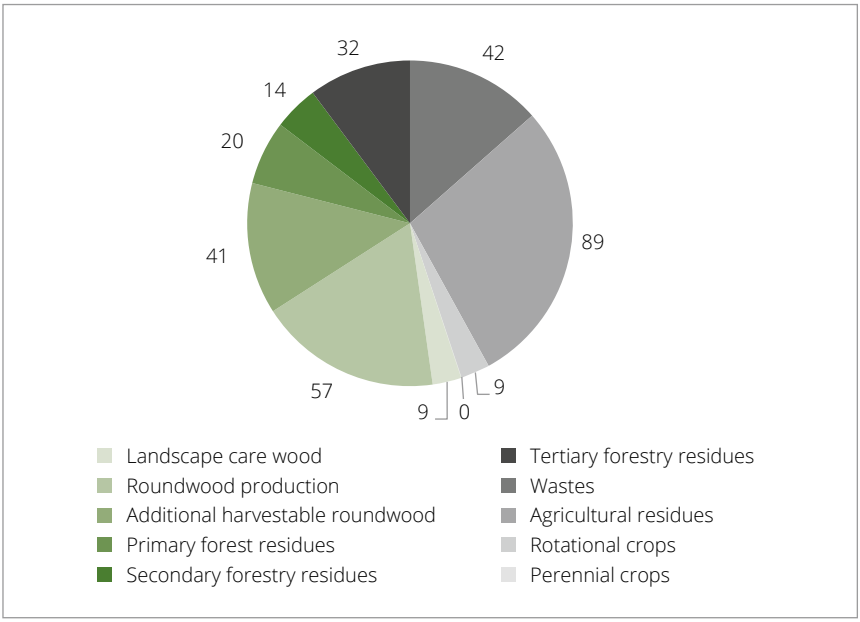

Figure 1: Available agricultural and forestry biomass in Europe (Source: Own Picture based on Elbersen et al. 2012).

Through interviews and literature research, we estimated available amounts and types of biomass sidestreams produced by farmers, foresters and companies in the hubs regions (table 1).

Biomass sidestream	Innovation Design Hub		
	Andalusia (Spain)	Ireland	Hungary
Olive pruning	2,524		
Olive leaves	345		
Olive pits	552		
Olive pulp	3,011		
Two-phase olive waste	3,544		
Straw	1,901	421	7,000
Grass		1,700	
Corn residues			14,000
Sunflower residues			1,000
Sugar beet industry residues			33,000
Fruit tree pruning			2,000
Apple pomace		5	
Spent mushroom substrate		240	12,000
Dairy sidestreams		200	60,000
Slaughterhouse waste	100	214	
Paunch waste		100	
Pig slurry	1,477	1,423	
Cattle manure	1,371	33,983	
Chicken manure	350	140	
Forest harvest residues			1,500
Panel industry residues		45	
Post-consumer wood residues		90	
Saw mill residues – bark		33	
Saw mill residues – sawdust		45	

Table 2: Rough estimation of agricultural and forest based biomass sidestreams (kton) available within the AGRIFORVALOR Innovation Design Hubs (Source: EU funded project AGRIFORVALOR).

From table 1 it follows that the different hubs each have their own specific palette of available biomass sidestreams. In Andalusia there is a huge availability of residues from the olive groves and industry. Ireland has large sidestreams of grass and manure from livestock. In Hungary there are a lot of dairy sidestreams, and of crop residues from sugar beet, corn and straw. Depending on the type of biomass sidestreams, different techniques to valorise the biomass sidestreams can be stimulated regionally. An overview of possible valorisation techniques for different biomass sidestreams and resulting outputs is presented in table 2.

Biomass sidestream		**Technique**	**Output**
Agriculture	Olive pruning	Hydrolysis Fermentation	Ethanol Antioxidants Oligosaccharides Lignin-derived chemicals
	Olive leaves	Extraction Hot water treatment	Tanning agents for leather
	Olive pits	Extraction	Polyphenols, bioactive compounds, nutraceuticals Animal nutrition Electricity
	Olive pulp	Anaerobic digestion Extraction Purification Combustion	Biogas
	Two-phase olive mill waste	Anaerobic digestion Extraction Purification Combustion	Biogas

»

Biomass sidestream		Technique	Output
Agriculture	Straw	Fermentation Combustion Pyrolysis	Biochemicals (lactic acid, succinic acid, laccase, cellulase, vanillin, ethanol, biohydrogen) Bio-fuels (ethanol, pyrolysis oil) Heat Compost
	Grass	Digestion Filtration Extraction Osmosis Mechanical separation	Food additives (flavour) Ingredients for cosmetics Bioplastics Biomaterials (e. g. Insulation, paper) Organic fertilizer Feed Biogas
	Corn residues (rachis, stem and leaf)	Fermentation Combustion Pyrolysis	Fuel Fertilizer Fine chemical
	Sunflower stem	Extraction	Cosmetics (skin cream)
	Sugar beet industry residues	Fermentation Combustion Pyrolysis Composting Acidification and gasification	Fuel (biogas) Fertilizer
	Fruit tree pruning	Extraction Purification Combustion	Pharmaceuticals Food additives Animal nutrition Electricity

»

Biomass sidestream		Technique	Output
Agriculture	Apple pomace	Digestion Extraction	Methane Ethanol Food additives (pectin, antioxidants) Food (apple syrup, jam)
	Spent Mushroom Compost	Digestion	Biogas Heat Fertilizer (compost)
	Dairy sidestreams (e. g. whey)	Hydrolysis Fermentation Anaerobic digestion	Nutritional additions (proteins) Bio-ethanol Biogas Fertilizer (N, P)
	Slaughterhouse waste	Incineration Pyrolysis	Fertilizer (N, P) Fertilizer (Bio-char)
	Paunch waste	Anaerobic Digestion	Methane Fertilizer (N, P)
	Pig slurry	Digestion	Biogas Minerals (P, N, K) Organic compost
	Cattle manure	Digestion	Biogas Minerals (P, N, K) Organic compost
	Chicken manure	Fluidised bed combustion Digestion	Heat Electricity Minerals (P, N, K)
Forestry	Wood based panel residues	Combustion Pyrolysis	Fuel / Heat / Power Pyrolysis oil Syngas Bio-char

»

Biomass sidestream		Technique	Output
Forestry	Post-consumer recovered wood	Chipping Combustion Pyrolysis Reuse / recycling	Fuel / Heat / Power Pyrolysis oil Syngas Bio-char Wood products from recycled wood
	Sawmill residues (Bark)	Chipping Combustion Pyrolysis Biorefinery Supercritical extraction	Filter material for bio-filters Mulching Heat / power Bio-char Syngas Bio-oil Tall oil (glue, paint, ink, bio-fuels)
	Sawmill residues (Sawdust)	Pelletizing Combustion Pyrolysis Supercritical extraction	Heat / power Bio-oil Syngas Bio-char Tall oil (glue, paint, ink, bio-fuels)
	Sawmill residues (Woodchips)	Combustion Pelletizing Pyrolysis	Heat / power Bio-oil Syngas Bio-char
	Pulp wood (excl. panel board use)	Chipping Combustion Pyrolysis	Heat / Power Bio-oil Syngas Bio-char
	Forest harvest residues (Lop and Top wood)	Brash harvesting Chipping Combustion	Heat / power

»

Biomass sidestream		Technique	Output
Forestry	Wood waste of forestry (logs, wood chips, wood cuttings, sawdust, branches, bark, etc.)	Chipping Combustion Pyrolysis Biorefinery Supercritical extraction	Filter material for bio-filters Mulching Heat/power Bio-char Bio-oil Tall oil (glue, paint, ink, bio-fuels)

Table 3: Overview of valorisation techniques and resulting output per sidestream (Source: AGRIFORVALOR, RTD compendium on research results on agriculture and forestry biomass sidestreams, C.M.A. Hendriks (Wageningen University & Research), E. Lambrecht (Gent University), G.J. Nabuurs (Wageningen University & Research), X. Gellynck (Gent University), H. Welck (S2i GmbH)).

For agricultural related biomass sidestreams, digestion, extraction, fermentation, combustion and pyrolysis seem promising techniques resulting in building blocks, intermediates and end products for use in the food, (fine) chemical, functional materials and fuel sector. For forestry related biomass sidestreams, extraction, combustion, pyrolysis, chipping and pelletizing are important techniques found to valorise woody sidestreams into marketable products such as heat, electrical power, fertilizer, bio-char, bio-oil and syngas. Mainly agricultural biomass sidestreams are valorised to food applications, probably due to its calorific value in combination with the cost-effectiveness of the techniques and biomass sidestreams. Techniques valorising forest sidestream biomass for food applications generally are in early stages of development (TRL 1–4).

2.1 Good practice cases of biomass sidestream valorisation

In the next section we present some of the good practice cases described in the AGRIFORVALOR project and that can be of use for further upscaling in Europe.

2.1.1 Bio-oil from forest based sidestreams

Fast pyrolysis is used to convert lignocellulosic biomass (e. g. saw dust, wood chips) through thermo-chemical decomposition into pyrolysis oil also known as bio-oil. The oil can be used to replace fossil fuels for means of transport that need high energy densities such as the marine sector. An additional advantage of the bio-oil is that it is low in sulphur which reduces emissions. The bio-oil can also be used in asphalt applications such as pavements and roof toppings. In January 2015 there was the start-up of the pyrolysis oil production facility in Hengelo, the Netherlands by Empyro BV. The Empyro plant converts per hour 5 tonnes of wood residues into 20 million litres pyrolysis oil, 80,000 ton process steam and 4,500 MWh electricity. By the use of bio-fuels the emission of CO_2 equivalents is reduced by 24,000 tonnes. A full scale biorefinery processing up to 15 ton / hour) is planned beyond 2020.

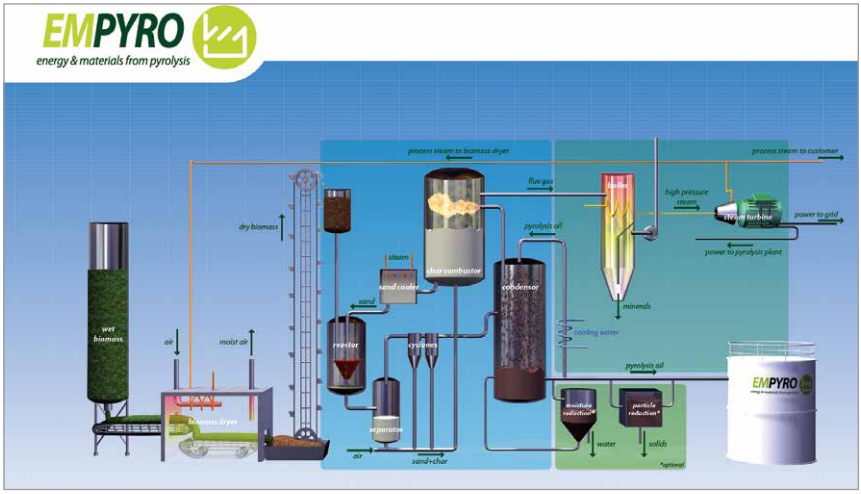

Figure 2: Pyrolysis installation for bio-oil (Source: BTG-BTL).

2.1.2 Mushrooms and biogas from agricultural crop residues

In 1997, Pilze-Nagy Kft., located near Kecskemét Hungary, started to grow oyster mushrooms, and in 2002 an oyster mushroom substrate plant was started producing 12,000 tonnes of substrate annually using mainly wheat straw from nearby farms as feed stock. After growing the oyster mushrooms, the waste substrate is used as feedstock for the production of biogas through anaerobic digestion. After use, the waste of mushroom substrate completed with pig slurry and ensiled maize is converted into 1.2 million Nm^3 of biogas. The biogas is used to produce 2,4 million kWh electricity which is fed into the grid and 2,68 kWh heat. A small part of the heat is used to keep the fermentation process in the digesters running. The major part is used for heating the oyster mushroom plant and for drying a part of the mushroom production. The digestate is used as fertilizer for nearby agricultural land. The plant required a 340 million HUF investment, which was partly an investment of the own company, partly a bank loan and a contribution of 110 million of the National Environment Protection and Infrastructure Operative Program.

Figure 3: Anaerobic digester converting spent mushroom substrate into biogas, heat and fertilizer (Source: László Somos).

Figure 4: Production location for oyster mushroom substrate (Source: László Somos).

2.1.3 Olive biomass sidestream in functional foods, food supplements and active pharmaceutical ingredients

Andalusia is the world's largest olive oil producing region, leading to typical and large biomass sidestreams from this type of land use and processing industries, such as olive stones, olive oil mill residues, olive leaves and pruning sidestreams etc. From these olive biomass sidestreams, bio-active compounds and nutraceuticals for cardiovascular health can be produced through extraction, purification and drying.

In 2011, Innovaoleo, an alliance between the world leader of olive tree production Oleícola El Tejar and the biotechnology company Natac was set up. This made it possible to commercialize innovative and value-added olive tree-derived ingredients for pharmaceutical, food and feed applications at really competitive prices on international markets. Natac specializes in extracts highly concentrated in oleuropein, hydroxytyrosol, and triterpenic acids, and has

developed innovative and highly effective olive tree-derived ingredients such as ALLOLIVE®.

Yearly, 1,000 tonnes of olive biomass are treated, resulting in 100 tonnes of bioactive compounds. After extraction of the high value compounds, the secondary biomass is combusted for the generation of electricity, leading to reduction of CO_2 emissions.

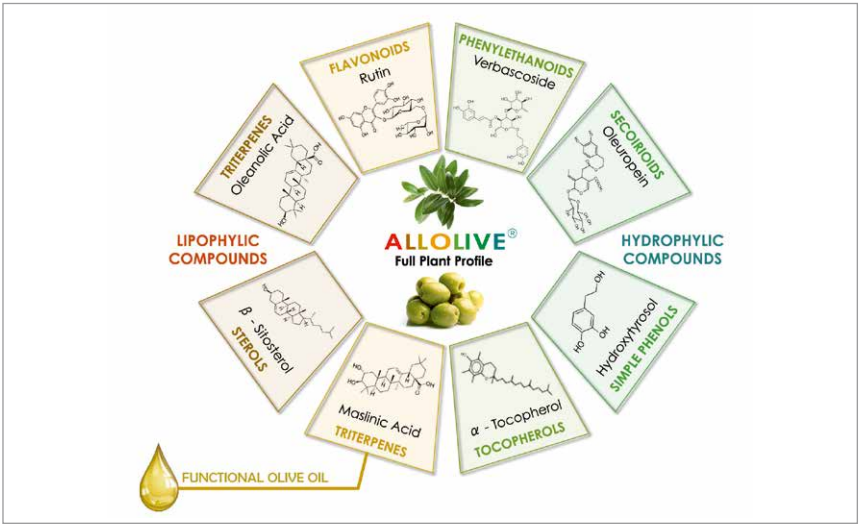

Figure 5: ALLOLIVE® Full plant profile: extract based on simultaneous concentration of compounds (Source: NATAC).

2.1.4 Wood pellets from sawmill by-products

Laois Sawmills, located in Portlaois Ireland, is processing 100,000 tonnes of logs annually. Logs are turned into products as fencing material, shed materials, decking, pallets, boards etc. While processing the logs to these products, a considerable amount of sawmill residues is produced such as sawdust, sander dust, trimmings, split wood, low quality logs, shavings. These by-products are converted into 32,000 tonnes of 6 mm wood pellets and 10,000 tonnes of dried wood chips for use as bio-fuels or horse bedding. The heat needed

for pellet production and drying of the wood chips is (partly) generated with wood residues that are not suitable for the pellet or chips production e. g. bark and non-workable wood residues. The Renewable Heat Incentive (RHI) in the UK stimulated pellets usage for heating and CHP purposes. The RHI in Ireland is expected to commence in 2018. Certification, e. g. the ENplus quality certification, is a major step towards establishing pellets as a widely used energy commodity.

Figure 6: Wood pellets from sawmill by-products (Source: Woodworking: flickr.com/oregondepartmentofforestry – CC BY 2.0: https://creativecommons.org/licenses/by/2.0/; Wood pellets: pixabay.com/Jai79).

2.1.5 Bioplastic, fine chemicals and natural fertilizer from grass

The biorefinery of Biowert, or the grass factory, is located in Germany with the development, marketing, strategic management, sales and distribution coordinated from Switzerland. At this location, meadow grass is processed into a high quality grass fibre and press juice. The fibres are mixed with different types of recycled plastic and applied in innovative materials, such as injection moulded products, flooring and insulation material. From the juice constituents are extracted for the production of flavours, cosmetics and feed. Also, a completely natural fertilizer is produced, as an ecologically sound alternative to conventional nitrogen fertilizers, further reducing the reliance on petroleum and reducing the potential impacts of livestock husbandry on the environ-

ment. For the plastic raw materials, the techniques used are the separation of fibres and green juice by using pressure, filtration and separation. For the production of flavours and cosmetic products ultra-filtration and reverse osmosis processes are used.

Figure 7: The Biowert Factory and products from grass: hangers, terrace profiles, cups, insulation material (source: Biowert Industrie GmbH).

3 The Sidestream Value Tool

An online tool to find information on valorisation of biomass sidestreams

In the AGRIFORFALOR project, an internet application is developed to present and seek out valorisation techniques and good practice cases: the Sidestream Value Tool. This is a web-based tool to share information, connect multi-actors and identify exploitation topics as well as to support the development of grass-roots ideas to be further developed as new business models. It also allows stakeholders to add more information on examples of innovations, techniques, research, partnerships and examples of pilot plants.

The tool contributes to an improved flow of information and communication on research results, good practice cases and knowledge between a multi-actor network of practitioners, academia, and business in order to deploy the vast reservoir of existing information and knowledge and to further exploitation of this.

By registering on http://agriforvalor.eu/sidestreams, users can search the database on sidestream biomass research results, practical applications and good practice cases in the EU and beyond.

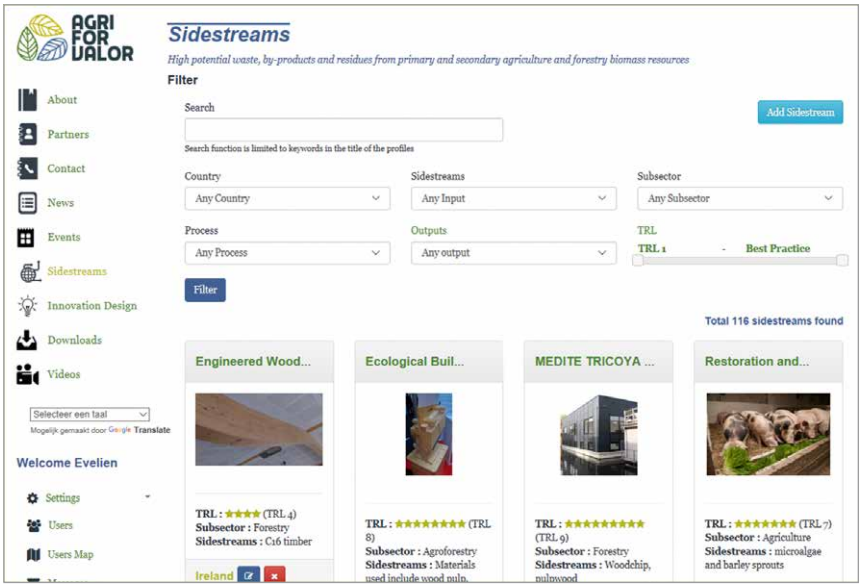

Figure 8: Interface of the sidestream value tool (Source: EU funded project AGRIFORVALOR, designed by GrowAbric).

4 Business cases for Andalusia, Ireland and Hungary

Examples of business cases are drafted, built upon the biomass sidestreams that are available in a large extent in the hub regions and promising techniques and innovations for that type of biomass and the specific region.

4.1 Valorisation of olive biomass sidestreams in Andalusia, Spain

Andalusia is the world's largest table olives and olive oil producing region, 30 % of the world's olive oil production and 20 % of the table olives are produced in Andalusia (Ministry of Education, Culture and Sports in Spain 2017). Hence, a large amount of olive groves related biomass sidestreams is available in this region, which can be valorised into a variety of products, depending on the type of olive biomass sidestream and the technique applied. For instance, milling residues from the olive oil industry can be used as feedstock for the production of biogas. Through anaerobic digestion (fermentation), biogas can be produced which can be used for heating purposes or power generation. In the fermentation process, the olive waste is used as co-substrate besides other biomass sidestreams such as manure and agricultural crop residues. Olive mill waste is rich in phenolic compounds affecting microbial activity of the fermentation process, which requires specific adaptation of the process. A successful installation, processing olive mill sidestreams, is the Campillos Biogas Plant in Andalusia, which is described in the section good practice cases in this article (Hendriks et al. 2016).

Figure 9: Olive grove and olive residues (mill waste, leaves and olives) (Source: Olive plantation: pixabay.com/ulleo; Mill residues: Cesar Díaz Barroso; Leaves: pixabay.com/ulleo; Olives: pixabay.com/Artvision-So).

Another opportunity is to valorise olive pomace and olive stones through extracting and purifying polyphenols and other bioactive compounds for food, cosmetics and pharmaceutical applications. After extraction of the high value compounds, the remaining biomass can be combusted or fermented for the production of heat or electricity. The Spanish biotech company Natac (www.natac.es) does already apply this technique on a commercial scale (see good practice cases in this article). In Italy, the EU project Bioactive-net, with important research on this topic, has developed a technique, which is close to the market (TRL9).

Figure 10: Natac manufacturing facilities, Spain (Source: NATAC).

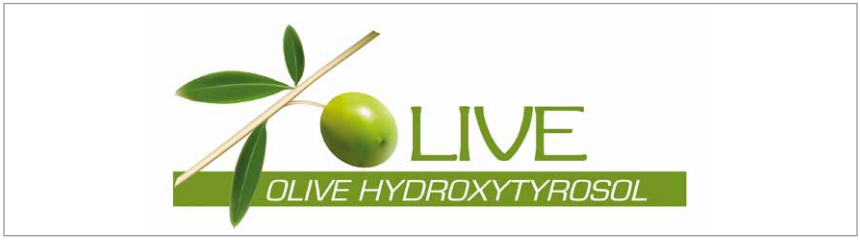

Figure 11: Anti-oxidant and anti-aging (Source: NATAC).

Another sidestream from the olive groves are the olive leaves, obtained during olive harvest and pruning of the trees. The leaves can be used for production of an ecological leather tanning agent by adding boiled water. Wet-green (www.wet-green.com), a German leather innovation centre, is performing this application on an industrial scale. Theoretically, 40 % of world's leather production could be facilitated with this olive based tanning procedure (wet-green® GmbH Innovationszentrum Leder & Kollagen n. d.).

Furthermore, a technique is developed by Andaltec Technological Centre and the University of Jaén (www.uja.es) to produce bioplastics from olive pruning.

Value chain and security of biomass supply

Although vast amounts of olive biomass sidestreams are available, they are scattered all over the region and transportation is one of the challenges to meet. Transportation costs can be minimized by partnerships collecting and processing the biomass on a regional or local scale, with installations adapted to the amounts of biomass available at the local scale. Seasonality in the availability of biomass can, in the case of the biogas installations, be overcome by using alternative feedstock such as manure and crop residues from farms in the region. A locally embedded valorisation of biomass sidestreams contributes to the sustainable socio-economic development of rural regions. Since large amounts of olive sidestreams are available, valorisation through biogas can be applied widely. As only a limited amount of reference projects exists in which a non-energetic, high value valorisation of olive biomass sidestreams is targeted, alternatives for biogas production should be considered and stimulated. For such application, more than 2,500,000 ton olive pruning, 345,000 ton olive leaves and 550,000 ton olive stones are available.

Environment

Sidestream management is very important in the olive oil supply chain, as the high phytotoxicity of the olive oil mill waste has large impacts on the environment, both land and water. In the valorising process, contaminants can be extracted and processed so they do not pollute the environment. Fossil fuels can be replaced by using rest products of the valorisation process as fuel by which CO_2 emissions can be reduced.

Policy support

Sustainable generation of biomass based renewable energy is supported by European policy. Spain needs to comply with the European legislation on climate and energy. To reach a 20 % cut in greenhouse gas emissions (from 1990

levels) and 20 % of its energy from renewable resources by 2020, the regional, national and European government have set out a strategic approach to foster bio-economy projects (European Commission n. d.). Biogas production through anaerobic digestion of olive waste can contribute to these policies as heat, electricity and bio-fuels are generated with the biogas produced. Subsidies are available to stimulate this transition.

Financial risk and access to finance

The current regulatory framework on biomass valorisation creates uncertainties in the sector, e. g. by imposing complex administrative tasks. As the economic feasibility of current business models is highly dependent on public subsidies, investors lose confidence and government subsidies are required. More changes have to be made to the current approach to construct a stimulating environment for biomass valorisation which also makes the private sector enthusiastic for investments.

Multi-actor networks

Strengthening existing networks can be a first step which might lead to the creation of private funding mechanisms for start-ups in the sector. Starting a biogas production plant will be more feasible when partnerships exist amongst (small) producers of olive waste, transport companies, and installation companies. Current cooperatives in the olive oil sector can be a starting point, which then become more attractive for investors. Besides networking, the governmental support can also be a safety net, preventing early drop out of start-ups. If a company is successful, it can take a next step towards techniques resulting in a higher valorisation value, e. g. by extracting specific compounds from the biomass prior to fermentation process. A cascading valorisation process of olive mill sidestreams shows large potential, but also requires a strong multi-actor-network.

4.2 Valorisation of grass sidestreams in Ireland

Figure 12: Irish Grassland (Source: Source: Improved grassland above the Head Road, cc-by-sa/2.0 – © Eric Jones – geograph.org.uk/p/2410395).

For the Irish hub, biorefinery of grass is one of the promising business models. A lot of grass surplus, above the needs to feed cattle, is available. This offers opportunities to valorise grass in other ways than for feed directly. For instance through grass biorefinery. In a biorefinery installation fresh or silage grass can be used as feedstock. Primary refining, by mechanical fractionation and pressing, results in grass juice and press cake which contains grass fibres. A green biorefinery is typically coupled with biogas production for which a part of one or both fractions (grass juice and grass fibre) is utilised as a co-substrate. The grass juice either goes directly into the biogas plant, or first some valuable ingredients (e. g. lactic acid, acetic acid, proteins, amino acids) can be extracted. Lactic acids can be used for production of bioplastics. The acetic acid, amino acids and proteins can be used for food and feed and cosmetic applications. The grass fibre can be processed into animal feed, or can be used as functional material, e. g. for insulation products, paper or fibre-reinforced synthetics. Grass biore-

fineries are not very common yet, but operational, commercial and demonstration plants already exist, e. g. Biowert in Germany (http://www.biowert.de/), Grassa in the Netherlands (www.grassa.nl) and Green Biorefinery in Austria (http://www.iea-bioenergy.task42-biorefineries.com/).

Figure 13: Grass fibres (Source: Biowert Industrie GmbH).

Value chain and security of biomass supply

Research shows that for Ireland the optimum scale for grass biorefinery is about 700–800 ha (O'Keeffe et al. 2012). Larger scale plants will require longer transport distances which negatively influences the economic viability. An added benefit of a decentralised biorefinery facility processing approximately 0.8 ton dry matter per hour, is that it allows for ease of operation and better knowledge of the source and quality of the grass being supplied. The most viable green biorefinery is one producing biogas and fibres. For the small scale installations, additional production of proteinaceous products does not affect the viability substantially. The continuity of feedstock availability throughout the year is guaranteed because besides green grass also silage grass can be used or a combination of both.

Green biorefinery can result in output of biogas, lactic acid, amino acids, fibre, fertilizer (P, N, organic compost) and feed. The biogas can be sold directly or used to produce power and heat for own use or for the grid. Lactic acid, amino acids and fibres can be sold to chemical, food or manufacturing industries for further refinery and high value products (e. g. paper and insulation material from grass fibres). Fertilizers can be applied on the own farm or sold outside.

Environmental issues

To produce biogas, the grass is mainly mixed with animal slurry / manure and then digested. This way surpluses of manure can be processed preventing over-fertilisation of agricultural land and pollution of (ground) water. The fermentation process typically produces two main products: biogas and digestate. The production of biogas reduces CO_2 emissions due to replacement of fossil fuels. From the digestate, fertilizers can be produced, reducing fossil phosphorus requirements. From the grass, fibres and chemicals can be extracted. The fibres and amino acids can be used for feed applications, reducing imports of protein concentrates. The fibres can also be used for insulation materials, paper and polymer composites. From lactic acid, bioplastics can be made, reducing the use of fossil fuels for the plastics. Through that greenhouse gas emissions can be reduced, most bioplastics can be recycled and some are biodegradable.

Policy support

A clear overarching policy on the Green Economy would facilitate innovation in the biobased sector. Incentives to promote biobased products are required for the development of new markets. Assistance is needed with the development of viable long-term market outlets and integration with development of the supply chain for bio-chemicals and bio-materials through e. g. specification and standardisation of bio-products, sustainability criteria for chemicals and materials, public procurement criteria etc. The new National Policy Statement on the Bioeconomy aims at more coherence across sectors, identification of fundamental challenges, and the development of a framework for implementation and engagement of key stakeholders. Although policy support is clear, this does not apply for the current financial support.

Financial risk and access to finance

The biorefinery technique can be applied on small scale which then also requires smaller investments compared to large scale installations. At local scale (cooperatives of some farms) a mobile biorefinery installation can be used (www.grassa.nl) requiring € 0.5 to 1.0 million investment with a throughput of 5 ton per hour. Investments for a small scale biorefinery with a feedstock throughput of 7,000 ton per year are € 7 million (O'Keeffe et al. 2012). Calculations on the economics of a large plant in Germany with a system capacity of 2 ton dry matter per hour of green waste and silage (ca. 91,000 ton per year) showed a required investment of € 15 million (Agency for renewable resources e. V. 2012). Large scale biorefineries are more suited to produce lactic acids (and other chemicals e. g. acetic acid and amino acids) on an economical scale than the small scale installations.

4.3 Valorisation of whey and straw in Hungary

In the Hungarian hub, large amounts of straw and dairy sidestreams are available. Straw can be valorised into various types of bioenergy. A first option is cogeneration of electricity and heat in a biomass-fuelled plant to supply energy in the region surrounding the power plant. An example exists in Pécs, Hungary (Veolia, http://www.veolia.com/en/heating-network-cogeneration-biomass). A second option is thermochemical conversion (pyrolysis) of the straw into bio-oil, syngas and bio-char. Biogreen provides an installation and technique for this process (Hendriks et al. 2016). Both techniques, cogeneration and pyrolysis can also use other biomass sidestreams as feedstock such as corn stover or forest based residues which are also available in huge quantities in Hungary.

Figure 14: Straw – a sidestream from wheat production (Source: maxpixel.net).

Figure 15: Whey – a sidestream from dairy production (Source: Author: Rebecca Siegel – CC BY 2.0: https://creativecommons.org/licenses/by/2.0/).

Whey, a sidestream of cheese production, can be valorised into various types of bioenergy or biochemicals. A first option is the fermentation of filtrated whey, containing lactose, into ethanol. Depending on the production process applied, the ethanol produced can be used for fuel, food, pharma or functional material applications. In Ireland, a good example of this technique can be found in the Carbery Milk Products company where whey permeate (protein removed) is converted to ethanol and the delactosed whey is converted to biogas (Hendriks et al. 2016).

Figure 16: The Carbery Plant, Ireland, can be a guiding example for Hungary (Source: Carbery).

Value chain and security of biomass supply

Hungary has a large area potentially suitable for producing agricultural and forest biomass, as the ecological and biophysical conditions are quite favourable. As a result, a high volume of biomass sidestreams is secured in Hungary. However, the biomass supply chain is fragmented. Creating multi-actor-networks, in which producers of biomass, transport companies, and installation companies collaborate, can improve required innovation substantially.

Environment

By valorising straw and forest residues for energy purposes, CO_2 emissions can be significantly reduced compared to coal and fossil oil fired power plants. The pyrolysis process, besides bio-oil, also produces biochar which can be used as soil amendment reducing soil emissions of greenhouse gases. Through fermentation of whey into biogas or bioethanol, a reduction of CO_2 emissions is possible. In addition, the residues of the biogas plant can be used as fertilizer.

Policy support

Hungary needs to comply with the European legislation on climate and energy, and reach a 20 % cut in greenhouse gas emissions (from 1990 levels) and generate 13% of its energy by renewable energy by 2020 (European Commission n. d.). Therefore, the national and European government have set out a strategic approach to foster bio-economy projects. Valorisation of straw and whey can contribute to these policies, which in turn can develop supporting programmes on these topics.

Financial risk and access to finance

Current regulatory framework on biomass valorisation creates some uncertainties in the sector, e. g. by imposing a top-down approach. For the moment, the economic feasibility of current business models is partly depending on private subsidies and crowd funding, as government subsidies are lacking. More changes have to be made to the current approach to construct a stimulating and financially feasible environment for biomass valorisation. Extension of existing multi-actor-networks can be a first step to achieve this. A better connection between stakeholders may lead to the creation of better private funding mechanisms for start-ups in the sector.

5 Recommendations at hub level

5.1 Recommendations for the Andalusian Hub

Recommendations were made for the Andalusian hub based on the existing environment, biomass availability and opportunities as well as examination of the needs and barriers of the regions. These recommendations relate to exploitation of identified technologies and regional bioeconomy business and market development. A summary of expected regional impacts resulting from the recommendations is also highlighted in the SIRA. The regional recommendations for Andalusia are described below.

5.1.1 Recommendations related to the exploitation of valorisation technologies

- Facilitation of the conversion of biomass resources by improving the availability of biomass so that they can be transformed into bioproducts and bioenergy, while advancing the sustainability (economic, social and environmental) of their production. Promote the implementation of Best Available Techniques (BAT) to increase the sustainability of the use of biomass resources.
- Identification of best techniques for collection, utilisation and pre-treatment in situ according to criteria of efficiency, effectiveness and profitability for the value chain of each biomass resource. The need to optimise the distribution of biomass resources to their place of transformation and the generation of new value chains for bioproducts and bioenergy make it necessary to take into account factors strongly related to logistics management such as the quantity and characteristics of resources, distance between the production areas and the collection centers or the points at which the users of the resources are located, all of which are key factors in their valorisation.

- Design and implementation of an investment plan to maintain and improve existing logistics infrastructures taking into account the importance of their location in rural areas. Promotion of the establishment of new centers for the preparation and collection of biomass resources adapted to the conditions of each territory, to facilitate their management.
- Improve the processes of pre-treatment of biomass resources and promote models that increase the eco-efficiency of their transformation. The efficient use of biomass resources depends, in many cases, on the performance of a set of previous processes (reduction of granulometry, reduction of humidity, densification or compaction of biomass, elimination of unwanted components etc.) that allow its conditioning and improve its valorisation in the subsequent transformation processes. In the same way, obtaining bioproducts requires the continuous improvement of the conversion technologies involved in their industrial production (physical, thermochemical, chemical, biotechnological etc.). In this line, it is of great interest to study the situation in which the available technologies are found.

5.1.2 Recommendations related to business model developments from the market point of view

- Promote new forms of public support and access to financing for the development and implementation of projects and business ideas in the bioeconomy (agreements with financial institutions, guarantees, participative loans, tax incentives, etc.), including alternative ways of collaborative financing (crowdfunding, crowdlending etc.) and new public-private financial instruments.
- Encourage and support the participation of knowledge agents and Andalusian companies in international networks for the development and implementation of R&D&I projects that enhance knowledge in the areas associated with the bioeconomy.
- Promote the realisation of economic feasibility studies and business models during the planning and implementation phase of bio-industries and biorefineries, mainly in rural areas.

- Review regulatory framework for biological waste and by-products to facilitate administrative procedures. Prepare and publish regulatory technical standards
- It is necessary to change business mentality in sectors as agriculture and forestry in Andalusia. They have traditional businesses, some of them are family businesses, so they need to open their minds to new business models, new technologies and international contacts to share information and experience for the use of biomass.

5.1.3 Regional impact expected by implementation of recommendations related to exploitation of existing technologies and to business model development

With the revision of the regulatory framework on biomass use and by-products recovery by the regional authorities and the publication of new regulatory standards, the Andalusian sector of biomass can be adapted to the requirements of new value chains on bioeconomy.

The problem of the logistic strategies for farmers and foresters will be solved by the optimisation of the distribution and logistics of the biomass to their place of transformation as well as its pretreatment insitu.

With the promotion of R&D&I projects and new business models about the valorisation of biomass, farmers and foresters will open their minds to new markets to create new businesses and new contacts.

5.2 Recommendations for the Hungarian hub

The SIRA Regional recommendations relate to exploitation of identified technologies and regional bioeconomy business and market development, including policy development. Building a supportive, transparent policy environment

seems to be the most important precondition to agree on a set of common principles for sustainable production and consumption and thus for a competitive bioeconomy in Hungary, including the setting of a bioeconomy strategy for the country. The rural communities need to be strengthened economically and socially to fully exploit the potential of a knowledge-based, sustainable circular bioeconomy. A summary of expected regional impacts resulting from the recommendations is also highlighted in the SIRA. The Hungarian recommendations are described below.

5.2.1 Recommendations related to the exploitation of valorisation technologies

- Both quantity and quality of communication between R&D and business sectors have to be improved in order to facilitate the uptake and deployment of research results into practice and the inputs of practitioners into research.
- Value optimisation has to be achieved by shifting to cascading type valorisation of biomass resources.
- To exploit synergies from collaboration, knowledge and technology transfer, a bioeconomy cluster acting as a multi-stakeholder network has to be developed having national rather than subnational regional competence, due to the relatively small size of the country. This cluster would be crucial, amongst others, in the regard of building new value chains mentioned above. Coordination, cooperation and networking activities will increasingly occur across the science, research, business and civil communities involved in this cluster, and involvement of policy coordination bodies and public authorities can be exploited much more effectively. Effective cooperation in this cluster and other formal or informal networks is also essential at local, regional and national level as well, to facilitate joint actions and exchange of knowledge between all the actors involved. The synthesising activity of the cluster can contribute significantly to a stronger industrial and innovation knowledge base as well as to the creation of the national bioeconomy strategy based on knowledge-based policies.

- In order to help release gridlocks in development and innovation processes, interactive, informal and thematic workshops have to be organised to foster strategic dialogue of all the stakeholders (private business sector, civil society, researchers and hopefully policy-makers as well) including foresight and thinktank-oriented activities.
- Interaction with a broad group of stakeholders and the public is critical to increase mutual understanding between actors and network activities in the bioeconomy domain, raise public awareness of bio-based products and boost engagement with policy makers.
- Enhance the cooperation between Ministry of Agriculture and research organisations, NGOs, as most of the bioeconomy-related activities from strategic initiatives to coordination of agricultural vocational education belong to this ministry.
- Support by experts should be given to small and medium sized enterprises willing to introduce a new biomass valorising technology, for mapping the related business opportunities and selecting the most appropriate technology.
- To improve inter-disciplinary skills, a new generation of dedicated multi-stakeholder actors has to be trained by engaging several public institutions and schools in bioeconomy education and awareness programs.
- Promoting demonstration of effective and profit-generating technologies and products can build investor confidence in the bioeconomy-linked applications.
- The importance of bioeconomy awareness programs is very clear at all levels amongst agricultural producers, with special regard to small family farms.

5.2.2 Recommendations related to business model development from the market point of view

- The innovation demand and performance have to be boosted by building new local value chains and presenting new business models or new modes of collaboration among market actors, because local supply chains are traditional and cooperation among industries or between various types of actors is rare and insufficient, thus inhibiting innovation, sharing of market and technology experience and knowledge (Mapping of EU Member States' / regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy, Task 3: Case Study Report Central Hungary region, Jan Vozáb, Berman Group, 2016). New value chains have to be built locally by rural development tools based on small-scale investments and on small-scale biomass processing, as neither the traditional nor the innovative value chains are fully exploited, and the opportunities for creating value added processes locally are low or missing . Even the renewable energy potential can be best exploited through decentralised small-region renewable energy generation, according to the "National Energy Strategy 2030" of Hungary.
- The valuable biomass resources and their processing has to be kept in Hungary. The biomass should be processed and utilized in Hungary itself in higher extent instead of exported, so the profit realised by processing the sidestreams, wastes, by-products of agriculture and food industry and producing high value added products can be realised by Hungarian companies. The existing potentials and advantages of the country can be lost if stakeholders do not pay attention to fully exploit these potentials.
- The allocation of sufficient financial, material and human capital to make the emerging technologies viable is very important. The actual market conditions should not be the only determining factor but a supportive national framework including funding opportunities would have to promote the development of innovative technologies, methodologies and approaches, in accordance with the EU-level programming structure.
- Not only the supply side but also the demand side towards biobased products needs to be mainstreamed, for example by 'conscious consumer' programs, in order to establish a better functioning market and to reach a

mature bioeconomy. A market formation has to be initialised at local as well as national level, as emerging technologies usually cannot compete with traditional technologies. Creation of artificial (niche) markets can contribute to the creation of a real demand for the emerging technology.

- Solutions being in line with circular bioeconomy are often not competitive against 'conventional' technologies (as renewable energy sources against fossil energy sources), primarily due to the fact that the external costs of the latter are usually not incorporated into their prices. Thus, in order to ensure the competitiveness of these innovative solutions, state incentives and financing is required. To support these incentives, market-driven technology developments which have already proven their operational efficiency and functionality have to be presented to political decision makers in order to ensure the possibility for a support system giving financial support to these bioeconomy-related initiatives which is independent from funds and grants. The financing support includes the following: direct production (market) support, investment support, interest rate subsidies, green financing (loans provided by state-owned financial institutions, refinanced credit programmes, guarantees for market loans, etc.), indirect production incentives (favourable tariffs, mandatory admixture ratios, tax advantages), state aid provided for R&D, training, information and promotional activities etc.
- The innovative developments can only and have to be made on a "step by step" basis, this is the only way they can move the companies towards the integration of small step actions leading to sustainable, circular processes. As regard to the bioeconomy innovation system, Hungary is lagging behind (together with other countries in the region) in adopting new technologies, that is why a graduated approach has to be applied to gradually increase consumer consciousness and societal acceptance, in parallel with business and market acceptance. The development of the organisations being transformed in accordance with the bioeconomy principles have to be continuous, dynamic and complex – just as the whole bioeconomy transformation.
- The transformative developments related to the bioeconomy innovations influence not only the entire production where they are implemented directly but also the industrial, business and market environment of the pro-

duction concerned. These developments can only be successfully integrated if all the other participants in the value chain will take the adequate steps to be a part of a sustainable system. Preferably the first innovative transformation will act as a pull for the other market players and serve as an engine for their developments matching the new value chain, contributing to the establishment of novel and more connected industries and markets. Obviously, this process takes time therefore transformation and national implementing measures should be given some time to be on a similar level with other EU countries having bioeconomy-linked policies in place for much longer time.

5.2.3 Regional impact expected by implementation of recommendations related to exploitation of existing technologies and to business model development

- The use of biomass can contribute to the retention of agricultural and forestry linked jobs and to the creation of new ones in rural areas.
- The use of by-products and wastes by converting them into valuable products or for local energy purposes will result in additional income for farmers and agricultural producers, and can reduce the need of communities for fossil energy sources.
- Integration of bioeconomy approach to industrial production and everyday life will result in local good practices and new value chains, and ensure better local opportunities and a viable local economy.
- Bioeconomy-related applications support the protection of the environment, biodiversity and soil quality, thus improving the competitiveness and sustainability of the region.
- Using a variety of measures e. g. multiple use of biomass resources, release gridlocks in development processes, and good practice cases – organisations involved in research, development, mentoring or networking activities can support the implementation of bioeconomy-related initiatives to increase the amount of biomass valorised in a way providing the most added value.

5.3 Recommendations for Irish Hub

Recommendations were made for the Irish hub based on the existing environment, biomass availability and opportunities as well as examination of the needs and barriers of the regions. These recommendations relate to exploitation of identified technologies and regional bioeconomy business and market development. Given the high levels of national emissions attributable to the agricultural sector in Ireland (second only to New Zealand in the OECD), the recommendations focus on the unique role that the bioeconomy can play in decarbonizing Ireland's economy, at the same time creating revenue for farmers, foresters and rural and coastal communities. It also highlights the need to address challenges of scale and focus on a cascading approach to biomass to produce high value products, rather than bulk energy-based products. A summary of expected regional impacts resulting from the recommendations is also highlighted in the SIRA. The regional recommendations for the Irish region are described below.

5.3.1 Recommendations related to the exploitation of valorisation technologies

Through AGRIFORVALOR a number of specific technological themes with regional potential for Ireland have been identified including:

- Second Generation Biorefineries: The deployment of industrial biotechnology offers the opportunity to replace existing fossil based products with new biobased ones. There is a growing awareness on the need to implement the cascade principle within the bioeconomy, to keep the value in products for as long as possible through multiple product uses followed by energy. Biorefineries are factories which allow the cascade principle to be put into efficient effect, through fragmentation of biomass into molecular or structural components which can be upgraded to value-added products. Biorefineries will offer new markets for farmers / foresters for underutilised residues highlighted by AGRIFOVALOR, supplementing traditional farm incomes. Building on the AgriChemWhey Flagship Biorefinery, new plants

for second generation biorefineries could be envisaged in Ireland utilising sidestreams such as :

- Lignocellulose
  (building on work of Libre, Booregaard and BIOSKOH),
- Brewers / Distillers residues
  (building on the work of Celtic Renewables),
- Horticulture Residues
  (building on the work of FUNGUSCHAIN and BIORESCUE).

- Small-scale bioenergy and biorefinery technologies: Small-scale biomass processing technologies can help to overcome a key barrier related to capital expenditure and improve the speed of innovation within the bioeconomy. From a regional perspective, small-scale technologies help to address the significant level of fragmentation seen in the national biomass supply chain and will also offer a route for greater farmer / forester participation in the bioeconomy.
- Valorisation technologies to achieve a cascading approach to biomass: With a fragmented supply chain, Ireland may struggle to meet the scale required for bulk bioenergy plants. There is therefore a need to ensure that a cascading approach to biomass is achieved with a focus on high-value, low volume products first to ensure biomass is targeted at its optimum value.
- Diversification of grassland: With grassland accounting for 90 % of agricultural land, grass biorefineries could represent a replicable model to help decarbonise existing agricultural activities, which currently account for 35 % of Irelands overall greenhouse gas emissions. Introduction of grass biorefineries could allow farmers to improve national fodder reserves and diversify their product base.
- Logistical issues: The SWOT undertaken in the Regional Innovation and Business Cases highlight lack of scale and supply chain fragmentation as a key weakness in the Irish bioeconomy. The development of biomass trade centres, or decentralised processing depots, could offer significant benefits in allowing scale to be better achieved but also to provide a regional location

which farmers / foresters can use to find markets for underutilised resources (e. g. brash and thinnings).

- Stakeholder networks: Local and regional bioeconomy strengths and opportunities vary and require individual strategies. To promote the development of a network of regional bioeconomies built on locally produced biomass and potential, greater information is required on regionally available feedstocks, costs, technology providers and potential value chains. The development of stakeholder networks demonstrated through the AGRIFORVALOR project, is vital to ensure all relevant actors in the value chain, from primary producers to end users, are engaged and that future regional operational groups and biobased SME's can be developed. Ireland currently imports large quantities of feed, chemicals, plastics and fuels. Connecting new biobased SME's into this market offers considerable opportunity for sustainable local employment and prosperity.

- Investment and access to finance to encourage technology uptake: To support technology uptake AGRIFORVALOR supports continued Investment in national bioeconomy activities. The Irish Government has recently provided key investments to support the Irish bioeconomy. This includes the provision of € 14.2 million (through Science Foundation Ireland) for a Bioeconomy Research Centre (Beacon) which will explore how to convert marine resources and the residues produced during food production into higher value products. The Government has also provided € 4.6 million in financial support through Enterprise Ireland's Regional Economic Development Fund for the establishment of a Bioeconomy innovation and piloting facility at Lisheen, Co. Tipperary, which will help companies to scale up operations for the first time, in Ireland. EU funding mechanisms such as the PPP, Biobased Industries Joint Undertaking (€ 3.4 billion), also represent a potentially key resource for Irish industries to scale up operations. The EU Commission also launched a Circular Bioeconomy Investment Platform in November 2017 through the Horizon 2020 SC-2 funding programme. This investment platform will be managed by the European Investment Bank. It is proposed that this public fund of € 100 million will leverage private capital to fund technological validation, scale-up and industrial biorefinery development. 2016 saw the establishment in Ireland of Sustainable Nation

Ireland, a national platform for the promotion of Ireland as a world-leading hub for sustainable finance, business and innovation, accelerating Ireland's transition to a low carbon economy. The organisation is aiming to stimulate € 250 billion private investment in green technologies and cleantech by 2021, while the government through the National Planning Framework 2040 Plan has earmarked 22 million euros for investment to turn Ireland into a low carbon economy by 2050.

5.3.2 Recommendations related to business model development from the market point of view

- Business Models and Collaboration: The Irish needs and barriers analysis highlighted that uncertainty around economic viability remains a critical barrier in exploitation of biobased innovations. The development of an ecosystem to support SME development in the biobased economy will help to bridge the research and innovation divide and overcome the valley of death. Providing researchers, entrepreneurs and primary producers with knowledge, market information and partners provides a key advantage in biobased enterprise development. In the biobased industry, for example, we see new products developed using biomass residues. Some are renewable but identical drop-in replacements for existing market products, others offer new functionalities with unique advantages when compared with existing products. The expectations and route to market in both cases will require very different strategies. It would greatly benefit SME's to learn about different approaches within the circular economy, including the experiences of existing players. Within AGRIFORVALOR, a pilot Bio-Enterprise Academy engaged SME's and primary producers, introducing case studies and business models from existing market players to detail the various steps in establishing successful biobased SME's e. g. identifying value proposition and bringing new products to market, piloting the use of a new circular economy canvas to allow participants to test and adapt their circular business model. Similar platforms would help to improve the speed of innovation within the bioeconomy.

- Developing an effective and supportive Bioeconomy Policy Strategies: In the Irish needs and barriers analysis respondents expressed concern that the bioeconomy policy environment in Ireland is not supportive enough to bio-industry start-ups, with lack of policy incentives seen as the greatest barrier. Developing the correct policy environment is an essential step in allowing the Irish bioeconomy to develop. It is essential that the right mix of push and pull measures are in operation. Recent Investments in R&D and National Piloting facilities are a first step (represent push measures), however it is important that the same commitment is provided in creating market access for new products (pull measures). Pull measures could include mandates and bans, public procurement, quotas, tax incentives, awareness creation, education, labels, certification and standards (push-pull). The Irish Bioenergy sector has been hindered in the past by poorly implemented (e. g. Bioenergy Establishment Scheme for Miscanthus and Willow) and delayed (Renewable Heat Incentive) strategies. Effective policy support is needed to give confidence to farmers, foresters and industry to become more involved in the bioeconomy. A Renewable Heat Incentive currently being implemented will help to open new markets for farmers and foresters. However, barriers including access to finance, grid connection and planning remain in place for farmers hoping to produce biogas. With bioeconomy research and innovation at an all-time high in Ireland, measures are needed to ensure that incentivising markets for energy production does not artificially inflate the cost of biomass for higher-value and more innovative uses. Therefore, a level playing field needs to be established. In certain jurisdictions, including Italy and the Netherlands, biobased economy has flourished in part due to effective policy support. In Italy, simple policy measures and initiatives have played a critical role in developing the country into an EU Bioeconomy powerhouse in less than a decade. These include the ban in 2011 of single use carrier bags, in favour of recycled or compostable bag, providing a clear route to market for industries, and the establishment of a dedicated green chemistry cluster to evaluate the skills and competencies nationally and to build capacity nationally to promote innovation in the bioeconomy. Development of a coherent and strategic bioeconomy roadmap is therefore essential in making sure that the potential of Ireland's bioresources are maximised.

- Financing the development of public private partnerships, clusters and cooperatives: Lack of access to finance was considered a key threat to the Irish Bioeconomy in the SWOT analysis undertaken by the Irish hub external experts. Enabling stakeholders along and across value chains to intersect and identify commercial opportunities is a critical step, however without dedicated and tailored funding instruments and funds, progression to tangible economic activity will continue to present a significant hurdle. For example, developing small-scale low-CAPEX models with improved automation represents a real opportunity for primary producers to become central players in the emerging bioeconomy. These technologies are available, however, financing options, routes to market and new collaborative models farmers and farmer organization wishing to diversify into new areas of the bioeconomy need to be addressed to encourage greater participation.
- Dedicated support professionals specifically trained in Circular Bioeconomy Enterprise development, funding and finance: The European Commission has made significant advances in developing financial instrument and funds for enterprise and industrial development. This includes the Circular Economy Finance Support Platform and a wide suite of financing packages from the European Investment Bank, which are very much not on the radar of the business community, in particular rurally based SMEs and primary producers. Local authorities supported by regional academic institutions can play a key role identifying, communicating and supporting regional bioeconomy business opportunities. Similarly, access to advisors with an expert understanding of the business, business model, planning, organizational and operational structures of enterprise operating within the Circular Bioeconomy will be essential to support this emerging sector. Therefore, investment advisors with a specific remit and training in the Circular Bioeconomy development is a critical need in the enterprise support and development offering in Ireland. This fits within the framework of the AKIS system and could readily absorb this form of skills diversification to develop the Advisors for the farms of the future.

5.3.3 Regional impact expected by implementation of recommendations related to exploitation of existing technologies and to business model development

Through implementation of these recommendations a number of impacts can be expected:

- Enterprise and Job creation: Creating an eco-system for biobased industries, start-ups and agro-forestry stakeholders to test and evaluate new business opportunities, whilst stimulating routes to market through policy and engagement will help to foster new enterprises and create local and rural employment. Particular focus on ensuring a promotion of cascading biomass will add value but also increase employment more than energy alone.
- Rural Regeneration: With 80 % of bioeconomy jobs expected to be created in rural areas, these are the big winners of a thriving bioeconomy. These recommendations support regional bioeconomy opportunities but also the opportunity for farmers and foresters to play a more central role in Ireland's bioeconomy, through uptake of small-scale, added value technologies, and the development of new business models and structures. Diversification of agricultural product base in the bioeconomy can also provide greater insulation from market fluctuations and BREXIT.
- Improved Sustainability: Providing a route to market for new sustainable products will allow consumers greater access to locally produced, sustainable alternatives. Through the bioeconomy, agriculture can provide sustainably produced products (decarbonising the agriculture sector) while the public can consume a greater level of locally produced sustainable products. This is a win-win situation. Coherent policy and supportive measures, both on the production, retail and consumer side are needed in order to achieve this.

5.4 Recommendations at EU level

The recommendations having an EU dimension are summarised in this chapter, based on common regional findings related to actions which need to be tackled on EU level rather than on regional level. The common areas include a focus on the cascade principle, the integration of small-scale technologies based on local business models, the continued development of support, training and multi-actor networks and the need for a supportive and coherent policy environment. These are described in more detail below.

1. **Shift from energy production towards higher value products and multiple use of biomass resources: multi-cascading use of biomass**

- Many regions in Europe have developed specific agricultural and forest cultivation using crops adapted to the regional climate and management following long cultural traditions. This, however, results in many regions in large quantities of biomass of the same kind which has advantages of scale, but also has disadvantages of vulnerability to volatile markets. Diversification of biomass and derived products from sidestreams strengthens outlets and, when regional processed, offers added value to biomass at a regional scale.
- At regional scale it might be hard to meet the scale required for bulk bioenergy plants and large biorefinery installations. There is therefore a need to ensure that a cascading approach to biomass is achieved with a focus on high-value, low volume products first to ensure biomass is targeted at its optimum value.

2. **Small-scale bioenergy and biorefinery technologies built in new local value chains applying circular bioeconomy business models achieving sustainability**

- Innovation demand and performance have to be boosted by building new local value chains and presenting new business models or new modes of collaboration among market actors.
- Small-scale technologies can provide a route for addressing the significant level of fragmentation on rural area.

- New sustainable value chains have to be built locally by rural development tools (e. g. multi-criteria analysis based on the 3Ps (Planet, People, Profit) approach) based on small-scale investments, on small-scale biomass processing and on local commitment by different stakeholders. Thus, offering a route for greater farmer / forester participation in the bioeconomy and a strengthening of rural communities and local / regional markets.

3. Expert support, training and multi-actor networks

- To shift to a circular bioeconomy, existing small and medium sized enterprises and new start-ups (including farmers) need support and training introducing innovative biomass valorisation technologies,
- identifying new approaches, business models and partners,
- mapping the related business opportunities and selecting the most appropriate technology.
- Effective cooperation in multi-stakeholder networks and clusters can help to exchange knowledge, strengthen the value chain and to test new business models. These organisations have to actively involve family farmers and foresters, researchers dealing with innovation projects, and local actors are needed to facilitate the networks in order to create working local bioeconomy communities.
- Awareness programs on the bioeconomy are needed to get familiar, gain trust and show good examples to small enterprises, farmers and foresters. These programs have to be able to prove sustainability of the bioeconomy-linked activities in a business environment, with special regard to the 3 P's (People, Planet, Profit) to integrate social, economic, and environmental / ecological preferences.
- Governmental support of multi-actor platforms contributing on knowledge exchange can facilitate credibility and functioning of bioeconomy initiatives.

4. Developing effective, coherent and supportive bioeconomy policy incentives and strategies

- Building on recent bioeconomy policies, it is critical that a supportive and coherent policy environment is developed which supports commercialisation, innovation and decarbonisation in the European bioeconomy. Each member state should elaborate a Strategy for its Bioeconomy with a clear action plan giving clarity about the direction of future policy creating a stable business environment.

- The report entitled "Leading the way to a European circular bioeconomy strategy" published in 2017 (Hetemäki et al.) describes very well the cause and effect relationships indicating the importance of the regulatory framework: "The key challenges were found to be the risks related to the market (demand) prospects, and uncertainties related to the regulatory environment. The first means that the demand for new bioeconomy products is still more uncertain than for the existing products. The latter relates to uncertainties over whether regulations affecting the markets in future are well-known, consistent and stable in the longterm. These are issues that have been raised by many studies for many years at the EU and Member State level, but which appear not to have been solved. Changes will not happen only by supporting new developments, there is a need to debase 'old', less efficient solutions too. Policy actions should demonstrate long-term regulatory commitment to support bioeconomy alternatives to fossil-based products targeting the entire products sector (now biased to bioenergy) and value chains while allowing free market forces to operate sufficiently."

6 Lignocellulose sidestream potential to close resource cycles to achieve a sustainable circular Bioeconomy

Biomass sidestreams play an important role in achieving a sustainable and circular bioeconomy, e. g. by enlarging the biomass feedstock basis without increased land usage and as they are non-food competitive (Bioeconomy Science Center n. d.). Also, in terms of quantity there still is a high unused realistic potential of agricultural and forest based sidestreams: for example in Germany, 16–20 Million Tonnes of Oil Equivalent (MOTE) (Dry Matter (DM)) for agriculture and 9–25 MOTE (DM) for forestry (Brosowski et al. 2015). In addition, biomass sidestreams offer several economic advantages, e. g. fibres from agricultural residues and their hybrids are 8–10 times cheaper than agricultural fibres from primary production, moreover it was demonstrated that these sidestreams are a better way of obtaining sustainable materials with better performance (Nyambo, Mohanty, Misra 2010).

In particular, (ligno)cellulose based sidestreams which are composed mainly of cellulose polymers, hemicellulose and lignin offer as virgin fibrous raw materials higher value application paths e. g. cellulosic materials for textiles and packaging, and lignin for resins or adhesives components for composite materials (Clusterinitiative Forst und Holz Baden-Württemberg n. d. and Corrado, Sala 2018). Moreover, ligno-cellulosic sidestreams are a broadly available primary, secondary and tertiary biomass sidestream from multiple agricultural, forestry and postconsumer sources – around 40 percent of all organic matter is cellulose (Practical Action n. d.) – like straw from cereals and corn, bark and chips from wood, fruit shells and stems, and vegetable roots. Postconsumer collected materials for recycling or the reuse of fibres from discarded paper, cardboards and unusable textiles are a valuable source of (ligno)cellulosic biomass. In this respect, (ligno)cellulose sidestreams from primary, secondary and tertiary biomass resources allow a wide range of higher material valorisation (recycling) options (Isikgor, Becer 2015).

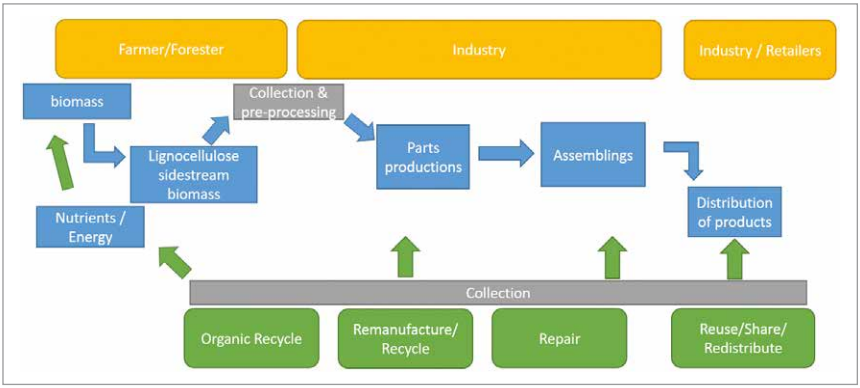

Figure 17: Circular economy model demonstrated with lignocellulose sidestreams (Source: Hartmut Welck, S2i).

In order to vastly exploit the great circular potential, different biomass resource cycles (natural and technical) need to be integrated to retain polymer, oligomer and monomer structures, thereby preventing landfill waste or incineration.

6.1 Biocomposite as vehicle to achieve closed resource cycles

Replacing classic fossil based materials with virgin (ligno)cellulosic fibres (based on sidestreams e. g. straw, leafs, kernels, bark, chips) and / or recycled (ligno)cellulosic fibres (e. g. waste cardboards, waste paper, unusable textiles) and natural binders (like waxes) and some water-soluble compounds can be applied as main components in the production of biocomposites. They emit less GHGs, are sustainable, a good source for energy savings and on top of that are recyclable or compostable, and can be applied for higher material applications – linking resource cycles. The agro and forest sectors are the principle suppliers of biomass related to virgin fibres. Therefore, farmers and foresters must be connected to new industrial logistics value chains and be informed about the value characteristics and multi-cascading potential of virgin fibres.

Biocomposites offer multiple opportunities:

- They have high upcycling potential, as they can be integrated into existing technical recycling systems.
- They are eco-friendly, non-toxic and biodegradable and can replace synthetic fossil materials up to 100 % and can hence play a crucial role for achieving sustainability goals.
- They offer a valuable compromise and upscaling potential as they are highly customizable in both physical appearance and performance characteristics.
- They are cost-competitive as they behave very similarly to traditional fossil based polymers, no expensive equipment overhauls or disruptive modification to manufacturing processes are necessary.
- They enable to close the loop between resource cycles as they can be made out of virgin fibres (involving agro / forest sector) and recycled fibres, from e. g. paper, cardboard and textiles or mineral fibres and be combined with different types of synthetic fibres, too.
- They offer farmers / foresters a new role in logistics value chains.
- They offer a broad market application e. g. for 3D printing, for structural or automotive applications, WPC in construction, granulates for injection moulding, bio-based thermoset resins and new polymers.

The following figure shows the potential of biocomposites for higher material applications closing resource cycles based on different sidestream inputs.

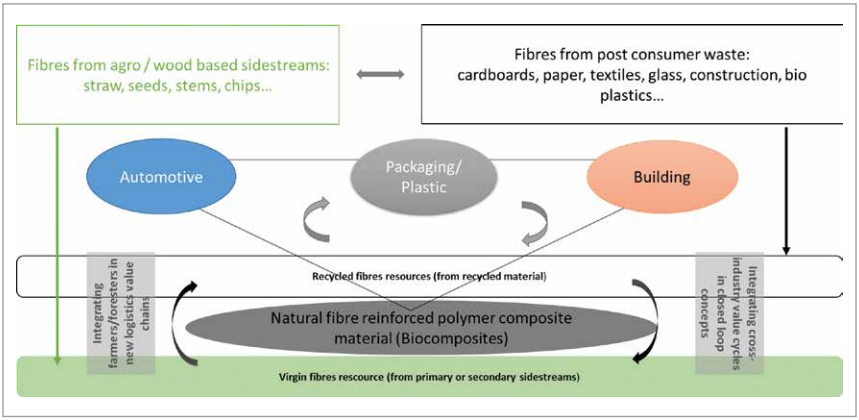

Figure 18: Closing resource cycles based on fibres from primary, secondary and tertiary sidestreams (Source: Hartmut Welck, S2i).

Promising practice examples are highlighting the way towards a sustainable circular Bioeconomy:

- Paper from grass (e. g. Biowert AG, Scheufelen GmbH & CO KG),
- Paper from fruit shells (e. g. FAVINI) or wood waste (e. g. UMP) or vegetable waste (Schutpapier),
- Biocomposites from wood residues and recycled plastic and paper (UMP Biofore),
- Biopackaging and carrier bags from wood-fibre pulp (Paptic Ltd.),
- Panels from local waste (e. g. cellulosic consumer packages and recycled cellulosic fibres (Noble Environmental Technologies Corp.),
- Textiles from wood pulp incl. paper pulp (Spinnova Ltd. and Infinited Fiber Company).

7 Conclusions

Biomass sidestreams have large potentials to contribute to Europe's policy on renewable energy and bio-based economy. Many new innovations are ongoing. This comprises research as well as building up experiences at pilot scale, market implementation and business development. A sustainable circular bio-based future is coming closer, but still a giant step has to be taken in this transition from a fossil fuels driven economy to a sustainable renewable and biobased driven economy. The transition will be stepwise building on recently developed techniques and working on new innovations trough research and development. Besides the local availability of biomass sidestreams, also local availability of knowledge, experience, culture and policy context will determine which valorisation techniques are most suited. Ability to learn and implement locally is very important for success. Connecting to multi-actor networks, including biomass producers, science, education, and the finance and business sector, is key for access to knowledge and business solutions and for achieving a sustainable bioeconomy. Biocomposites offer a vast opportunity to integrate resource cycles by linking primary, secondary and tertiary sidestreams.

The three biomass innovation design hubs in the AGRIFORVALOR project all show good possibilities for valorisation of biomass sidestreams. Andalusia, being the world's largest olive producing region, has vast amounts of olive sidestreams which have potential for energy production (e. g. biogas through fermentation) and high value applications such as constituents for cosmetics, pharmaceuticals, food additives, leather tanning products and bioplastics. The techniques are in different stages of development from lab scale to fully commercial operational. Developing a wide palette of techniques to valorise the different types of olive sidestreams contributes to strengthening the business model of local olive cooperatives and through multi-actor-networks also to the socio-economic sustainability of the region.

A potential business case in Ireland can be built around grass biorefinery. The surplus of grass, not needed as feed, can be used in biorefineries to produce biogas for energy, fertilizers, fibres for paper and packing materials, (high protein)

feed, and platform bio-chemicals (e. g. lactic acid, bio-ethanol etc.) for bioplastics. Some products can be produced and used on the farm scale (e. g. biogas, fertilizer and feed) while bio-chemical production due to economics of scale can be better produced in large scale installations. Also combinations of small and large scale installations are possible. The small scale biorefineries, suited for cooperatives of farmers and multi-actor-networks, strengthens the business models of farms who experience fluctuating commodity prices.

The large available amounts of whey, as a sidestream from cheese production, offers opportunities for different valorisation techniques in Hungary. Through fermentation, ethanol or biogas can be produced. The ethanol can be used for food, pharmaceuticals, bioplastics or fuel. The biogas is typically used for heat and power generation, which can be for own use, or for the grid. Installations need a certain scale of economics but it can be owned by for instance a farmers cooperation.

AGRIFORVALOR has been translating it's findings into recommendations for a demand-driven research agenda (SRIA). Individual hub recommendations are made across the 3 hubs Ireland, Spain and Hungary with common areas summarised into broader EU recommendations including:

- The need to shift from energy production towards higher value products and multiple use of biomass resources: multi-cascading use of biomass,
- The need to think local and small: the promotion of small-scale bioenergy and biorefinery technologies built into new local value chains applying circular bioeconomy business models achieving sustainability,
- The need for expert support, training and multi-actor networks to develop regional bioeconomies across Europe,
- The development of effective, coherent and supportive bioeconomy policy incentives and strategies.

Literature

Agency for renewable resources e.V. (FNR) (2012): Biorefineries Roadmap, as part of the German Federal Government action plans for the material and energetic utilisation of renewable raw materials. Berlin, Germany. https://www.bmbf.de/pub/Roadmap_Biorefineries_eng.pdf, last access: [10.10.2018].

Bioeconomy Science Center (n. d.): Research programme, https://www.biosc.de/research_programme, last access: [15.10.2018].

Brosowski, André; Thräna, Daniela; Mantau, Udo; Mahro, Bernd; Erdmann, Georgia; Adler, Philipp; Stinner, Walter; Reinhold, Gerd; Hering, Thomas; Blanke, Christian (2015): A review of biomass potential and current utilisation – status quo of 93 biogenic wastes and residues in Germany, in: Science Direct, Vol. 95, p. 257–272.

Clusterinitiative Forst und Holz Baden-Württemberg (n. d.): http://www.cluster-forstholz-bw.de/foerderung-bis-2013/potenzialanalyse-lignocellulosen.html, last access: [25.10.2018].

Corrado, Sara; Sala, Serenella (2018): Bio-Economy Contribution to Circular Economy. In: Benetto, Enrico; Gericke, Kilian; Guiton, Mélanie (eds), Designing Sustainable Technologies, Products and Policies. Springer, Cham.

Elbersen, Berien; Startisky, Igor; Hengeveld, Geerten; Schelhaas, Mart-Jan; Naeff, Han (2012): Atlas of EU biomass potentials. Deliverable 3.3: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources. BIOMASS FUTURES project – IEE 08 653 SI2.529 241, European Union-Intelligent Energy Programme.

European Commission (n. d.): 2020 climate & energy package, https://ec.europa.eu/clima/policies/strategies/2020_en, last access: [10.11.2018].

Hendriks, Kees; Lambrecht, Evelien; Vandenhaute, Heidi; Welck, Hartmut; Gellynck, Xavier; Nabuurs, Gert-Jan (2016): Good practice cases in practical applications of agro and forestry side-streams processing. Deliverable 1.2. EU-Horizon2020 project AGRIFORFALOR, Project ID: 696394.

Hetemäki, Lauri; Hanewinkel, Marc; Muys, Bart; Ollikainen, Markku; Palahí, Marc; Trasobares, Antoni (2017): Leading the way to a European circular bioeconomy strategy. From Science to Policy 5. European Forest Institute.

Isikgor, Furkan H.; Becer, C. Remzi (2015): Lignocellulosic Biomass: A Sustainable Platform for Production of Bio-Based Chemicals and Polymers, in: Polymer Chemistry, Issue: 25, 4497–4559.

Ministry of Education, Culture and Sports in Spain (2017): The Olive Grove Landscapes of Andalusia, 2017, https://whc.unesco.org/en/tentativelists/6169/, last access: [15.10.2018].

Nyambo, Calistor; Mohanty, Amar K.; Misra, Manjusri (2010): Polylactide-Based Renewable Green Composites from Agricultural Residues and Their Hybrids, University of Guelph, Ontario.

O'Keeffe, Sinéad; Schulte, Rogier P. O.; Sanders, Johan P. M.; Struik, Paul C. (2011): II. Economic assessment for first generation green biorefinery (GBR): Scenarios for an Irish GBR blueprint. Biomass and bioenergy 41: 1–13. doi:10.1016/j.biombioe.2011.11.018

Practical Action (n. d.): http://www.sda-uk.org/materials/popups/plastics/what_are_biopolymers.htm, last access: [10.01.2019].

United Nations secretary-General's high-level panel on Global sustainability (2012): Resilient People, Resilient Planet: A future worth choosing. New york: United Nations.

wet-green® GmbH Innovationszentrum Leder & Kollagen (n. d.): Environment, http://www.wet-green.com/umwelt_engl.php, last access: [22.10.2018].

AGRIFORVALOR is a thematic network-project funded by Horizon 2020 of the EC. Its focus is on exploiting the valorization potential of biomass sidestreams (high value waste, residues, discards) from agriculture and forestry by facilitating innovation partnership networks aligning multi-actors from agriculture and forestry with the business and research community piloted in three hubs: Hungary, Ireland and Andalusia (Spain).

Sidestreams' role in achieving a sustainable Bioeconomy is important as to broaden the feedstock base without increased land usage and as they are non-food competitive.

In addition, high value "wastes" from forestry, agricultural and agro- / forest-industrial, are accumulated every year in large quantities causing serious environmental problems. Moreover, these high value wastes are in majority still converted into energy at low added value. However, they could be utilized for the production of a number of higher value added products and in addition, circular concepts can be successfully applied to biobased production chain in terms of "waste" valorization as each step in the supply chain of bio-based products may provide sidestreams with different characteristics, which can be valorized in various ways.

Agriculture and forest sectors are important players and enablers of Bioeconomy and circular economy concepts. In order to profit from these opportunities knowledge and innovation networks and new business models are needed to develop and efficiently manage alternative processes fostering new industrial value chains.

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