Potential of biomass sidestreams for a sustainable biobased economy

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

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Author(s):

Kees Hendriks[1], Evelien Lambrecht[2], Heidi Vandenhaute[2], Hartmut Welck[3], Xavier Gellynck[2], Gert-Jan Nabuurs[1]

[1] Wageningen University and Research
[2] University of Ghent
[3] Steinbeis 2i GmbH

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Content

Abstract

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, 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 developed; 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. Also a web-based tool is developed, making this information easily available for stakeholders such as foresters, farmers, the biomass processing industries and the bio-energy sector.

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 takes 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 root ideas for bio-industry development.

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.

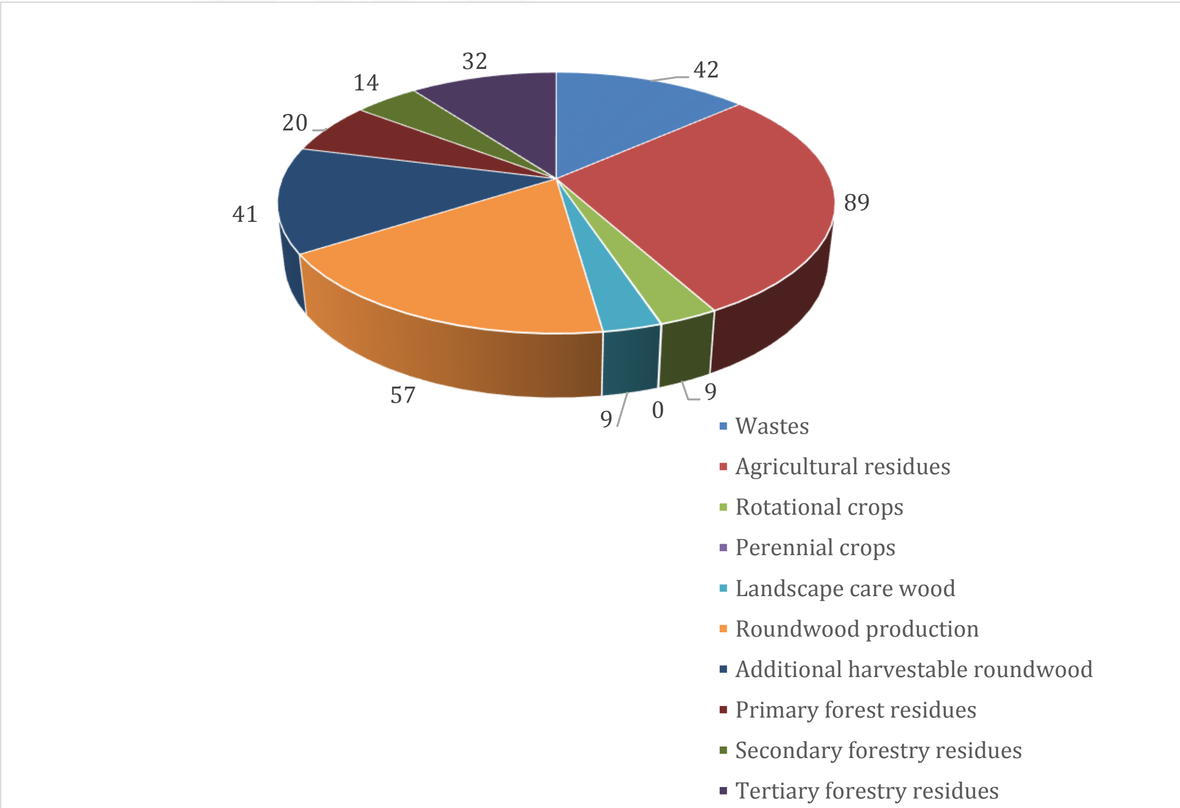
In literature and on the web, a vast number of research techniques and good practices can be found. To make this information more clear, the AGRIFORVALOR project drafted an overview of valorisation techniques and good practice cases and a web based tool making this information easily available for stakeholders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

1.2 Outline of the article

This article summarizes some practical information from the AGRIFORVALOR project and starts with an overview of available biomass sidestreams, with their possible valorizing 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 root 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. 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. Elbersen et al. 2012). 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.



Available agricultural and forestry biomass in Europe (source: 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).

Table 1: Rough estimation of agricultural and forest based biomass sidestreams (kton) available within the AGRIFORVALOR Innovation Design Hubs

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	

From table 1 it follows that the different hubs each have their own specific palette of available biomass sidestreams. In Andalusia 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 valorization techniques for different biomass sidestreams and resulting outputs is presented in table 2.

Table 2: Overview of valorisation techniques and resulting output per sidestream

	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
	Straw	Fermentation Combustion Pyrolysis	Biochemicals (lactic acid, succinic acid, laccase, cellulase, vanillin, ethanol, biohydrogen) Biofuels (ethanol, pyrolysis oil), Heat Compost
	Grass	Digestion Filtration Extraction Osmosis Mechanical separation	Food additives (flavour) Ingredients for cosmetics Bio-plastics 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
	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 (P, N) 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
	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, biofuels)
	Sawmill residues (Sawdust)	Pelletizing Combustion Pyrolysis Supercritical	Heat/power Bio-oil Syngas Bio-char

		extraction	Tall oil (glue, paint, ink, biofuels)
	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
	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, biofuels)

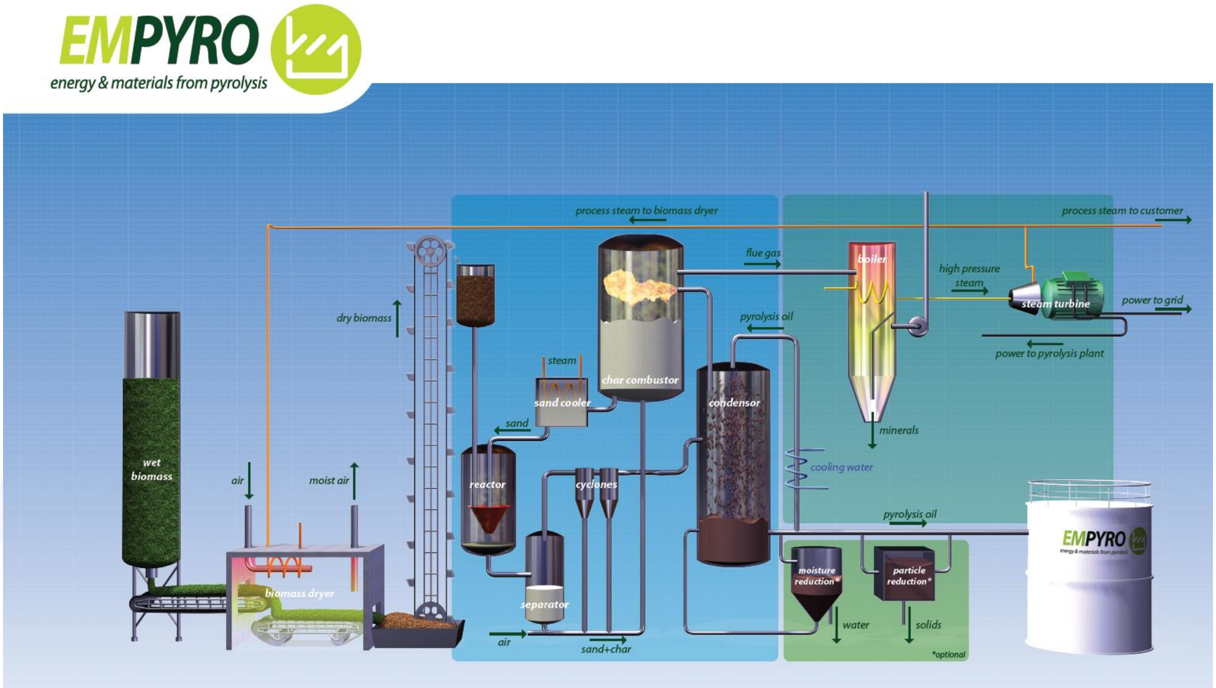
For agricultural related biomass sidestreams, digestion, extraction, fermentation, combustion and pyrolysis seem promising techniques resulting in building blocks, intermediates and end products for use in the food, (fine) chemical, functional materials and fuel sector. For forestry related biomass sidestreams, 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 side-streams. 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 valorization

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 biofuels 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.



Pyrolysis installation for bio-oil (Source: btg-btl.com)

2.1.2 Mushrooms and biogas from agricultural crop residues

In 1997, Pilze Nagy company 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.

Anaerobic digester converting spent mushroom substrate into biogas, heat and fertilizer (Source: www.pleurotus.hu)

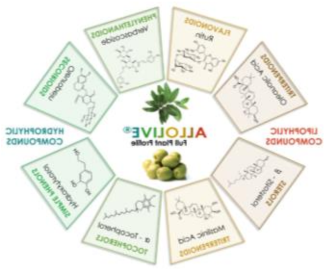
Production location for oyster mushroom substrate (Source: www.pleurotus.hu)

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

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.



ALLOLIVE Full plant profile: extract based on simultaneous concentration of compounds (Source: www.natac.es/innovaoleo-by-natac/?lang=en**)**

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.

Wood pellets from sawmill by-products (Source: www.laoissawmill.com**)**

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 constituentsare 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 environment. 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.

Products produced from grass: injection moulded products, terrace profiles, ballpoint-pen, insulation material (source: www.biowert.de)

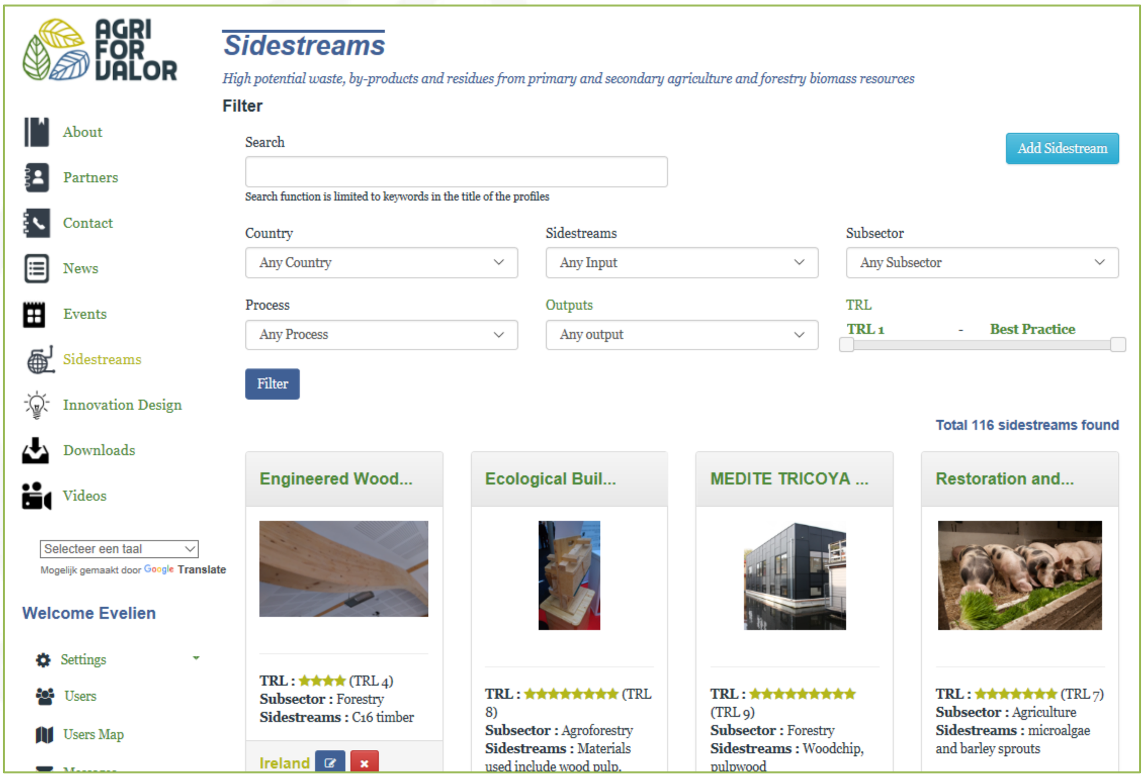
3 The Sidestream Value Tool

An easy tool to find information on valorisation of biomass

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 root 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.



Interface of the sidestream value tool (source www.agriforvalor.eu/sidestreams)

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. 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).

Olive grove and olive residues (mill waste, leaves and stone)
(source: www.iberianfields.com**;** www.agchemigroup.eu **;** www.etsy.com **;** www.livingcirculair.veolia.com **)**

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).

Natac manufacturing facilities, Spain (Source: www.natac.es)

Anti-oxidant and anti-aging (Source: www.natac.es)

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.

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 550,000ton 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. Biogas production through anaerobic digestion of olive waste can contribute to these policies as heat, electricity and biofuels 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

Irish Grasland (Source: www.geograph.ie)

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 bio-plastics. 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 biorefineries 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/).

Grass fibres
(Source: www.biowert.de)

Feed – fibres with proteins
(Source: www.grassa.nl)

Value chain and security of biomass supply

Research shows that for Ireland the optimum scale for grass bio-refinery 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 bio-refinery 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 at the own farm or sold external.

Environmental issues

To produce biogas, the grass is mainly mixed with animal slurry/manure and then digested. So 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, bio-plastics can be made, reducing the use of fossil fuels for the plastics, and through that reduce greenhouse gas emissions, most bio-plastics 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 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 than 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 bio-refinery 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 (FNR 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 exist 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.

Straw a sidestream from wheat production (Source: Max Pixel)

Whey a sidestream from dairy production (Source: www.cheesemaking.com)

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).

The Carbery Plant, Ireland, can be a guiding example for Hungary (Source: www.carbery.com)

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 substantial.

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 13% of its energy from renewable resources by 2020. 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 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.

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 bio-plastics. 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 strengthen 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 bio-plastics. 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, bio-plastics 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.

6 Literature

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