Ref. Ares(2019)6423244 - 17/10/2019

ICT - BIOCHAIN

Deliverable 2.1
REGIONAL BASE DEFINITION REPORT

Acronym:	ICT-BIOCHAIN
Project title:	ICT Tools in Efficient Biomass Supply Chains for Sustainable Chemical Production
Contract Nº:	H2020-BBI-JTI-2017 - 792221
Start date:	1st June 2018
Duration:	24 months

Deliverable number	D2.1
Deliverable title	Regional base definition report
Submission due date	M2 – August 2018
Actual submission date	31/08/2018
Work Package	WP2
WP Lead Beneficiary	CTA
Dissemination Level	Public
Version	03

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 792221

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Version history

#	Reviewer	Comments
00	CTA	Document creation
01	CTA	Document revised by CAPDER and ITT
02	CTA	Integrated version
03	CAPDER, ITT, IBF	Final version

Executive Summary

The present document summarises the regional baseline that will be considered as starting point for the development and implementation of ICT-BIOCHAIN activities.

In the case of South-East Ireland, biological sectors are responsible for significant employment, producing substantial volumes of outputs with formidable financial value, and playing a role in feeding an ever-growing global population. Main opportunities have been found in the agri-food and forestry value chains. The residues which arise from their processing include whey residues from cheese or casein production, dairy fat from milk processing, spent mushroom compost and stalk cut-offs from mushroom production, various sludges from wastewater treatment, food crop residues from apple, potato, and other food processing, lignocellulose from the wood processing sector, spent grains from the brewing and distilling industry, animal by-product from meat processing, and manures from the livestock sector.

In terms of feedstock, Andalusia has a very strong position due to the importance of the agricultural sector and forestry. Waste products and oils, derived from the olive groves (pruning, mill leaf, olive pomace, olive marc, and olive pit) are a large and attractive feedstock for new value chains. The fact that Andalusia is the major olive producer and olive oil biobased industries are well developed, could result in economics of scale or build on specific oil refining expertise which allow it to be more competitive than other European regions. Fruit and vegetables are important because of the high volumes of vegetable remains involved in intensive horticulture. For forest feedstocks, lignocellulosic value chains could be established towards paper, composites, polymers or chemicals. Furthermore, due to its sunny climate and intensity of solar irradiation (because of Andalusia's Southern location), cost-effective algae cultures are a promising feedstock and a huge opportunity for high quality proteins and bioactive compounds production causing relevant progresses.

Regarding ICT, IoT and Industry 4.0 both regions have several solutions available in the market that aim to make farmers work easier. These products are usually focused on retrieving data and handling them in order to make the most out of available information. This goes from traceability and information availability for the consumer/biomass buyer to integration of information with weather forecast and plagues information in order to reach a cost and resource efficient planification and management of crops and farms. Nevertheless, there are no relevant or outstanding solution related to biomass logistics, being this a clear gap towards the sector full digitalization.

Concerning the past experiences with Digital Innovation Hubs (DIHs) in each region, both have conducted previously several interesting initiatives that will serve as foundations for ICT-BIOCHAIN DIHs. In the case of South-East Ireland, most relevant past initiatives are: Manufacturing Industry Digital Innovation Hub, Dingle Creativity and Innovation Hub, Smart Agri Hubs and Dublin Digital Hub Project. As for Andalusia, these are DIH Andalusia Agrotech, Andalusian Bioeconomy Cluster, Linares 4.0, Knowledge City (DIH), OnGranada - Granada Plaza Tecnológica y Biotecnológica and National Pole of Digital

Content, POLO. It is expected that a lot of synergies between and ICT-BIOCHAIN can be stablished. In both cases, regions pointed out as main barrier demonstrating industry relevance and benefits to the different industries (and other) partners. Another challenge identified is the geographic fragmentation of companies associated with the hub and the technology providers which can make technology access or demonstration more difficult to achieve. Main lessons learned from these experiences are: (1) relevance of understanding of the needs of industries participating; (2) big impact of a demonstration day when industry (rather than academia or technology providers) discuss the technologies that they have integrated, and inform stakeholders about the way in which this technology has improved efficiency or added value to their process; and (3) importance of communication and dissemination plans as well as a well-formed DIH service definition.

Finally, regarding the barriers identified for the implementation of the ICT-BIOCHAIN DIH, most of them are common for both regions. It is possible to group them around stakeholder involvement (e.g. lack of motivation from biomass suppliers to improve their local supply chains, ow stakeholder involvement and meeting the needs of industry/stakeholders), information availability (accessing information on existing technologies/best practices, knowledge gap within companies and low data availability and specific applications to bioeconomy) and DIH regional definition (lack of regional focus, low coordination between value chain stakeholders, legal form for the DIH establishment, definition of DIH value proposition and lack of specific financial instruments). A preliminary identification of means to overcome these barriers is presented in this deliverable, being further plans developed in the frame of WP2.

Content

Acronyms and abbreviations

ACRONYM	DESCRIPTION
(EU)	European Union
(EC)	European Commission
(ICT)	Information and communication technologies
(IoT)	Internet of Things
(MDR)	Model Demonstrator Region
(DIH)	Digital Innovation Hub

1 Introduction

The biomass sector is a strategically relevant economic sector for the European Union (EU). However, the sector faces new challenges, some of them being similar to those from the agri-food sector. These challenges include the potential that information and communication technologies (ICT) offer, but also the disruptive effects they can have on the current practices and habits of value chain actors (farmers, food manufacturers, biomass processors, transport, retail and of course end-users/consumers). The biomass value chain has different characteristics respect to other industries value chains so consequently, there is a need for specific types of information and data management systems. The large volume and diverse nature of the data, including both structured and non-structured data, calls for specific integration and management procedures to make the most of the new economic opportunities based on information, data and cognitive technologies. Industry 4.0 approaches could bring as well novel solutions that could contribute to unlocking European biomass potential.

In the frame of the ICT-BIOCHAIN project, the application of these approaches (ICT solutions in general) as tools for improving logistics in biomass value chain will be boosted through the implementation of two Digital Innovation Hubs. These will be located in South-East Ireland and Andalusia, as these regions has been selected as Model Demonstrator Regions for sustainable chemistry by the European Commission (EC) thanks to their immense potential for Biobased Economy.

Concerning South-East Ireland, the Lisheen Mine, a decommissioned lead and zinc mine located in Tipperary, South-East Ireland, is today the epicentre of Ireland's National Bioeconomy Campus and one of six designated EU Model Demonstrator Regions for Sustainable Chemical Production. The former lead and zinc mine began production in 1999 and ceased mining in November 2015 having exhausted all commercial parts of the ore body. The mine had successfully operated for 16 years and in 2013 a task force was established to examine alternative options and uses for the 455-hectare property post closure. Tipperary County Council, in conjunction with the Southern and Eastern Regional Authorities made an application to the European Commission for designation as a Model Demonstrator Region for the Production of Sustainable Chemicals. Twenty-eight regions within the EU applied for the designation and Lisheen was one of the six successful regions. The application had the support of a number of businesses from the Agri-Food sector and involved processes that will extract residual value from agri and food waste streams. Having ceased mining in November 2015, the mine has since undergone significant surface and underground rehabilitation, in its conversion to a bio-economy campus that is well served by power, water and waste disposal infrastructure. Vedanta, an Indian based company is the owner and operator of Lisheen.

The Irish Bioeconomy Foundation CLG was established in mid-2016 as a vehicle to bring together relevant stakeholders with an interest in establishing a National Bioeconomy Hub at Lisheen. In 2016 €100,000 funding was secured from the Rural Economic Development Zone (REDZ) funding from the Department of Arts, Heritage, Regional, Rural

and Gaeltacht Affairs in December 2016 to facilitate the completion of a feasibility study into the provision of a Bioeconomy Pilot Scale facility in Lisheen. The scope of this study was to assess the viability of repurposing the Lisheen lead and zinc mining site for production of biobased chemicals through new forms of cooperation among industry, research and agriculture. In 2017, Enterprise Ireland, through its Regional Enterprise Development Fund awarded €4.6 million to support the Irish Bioeconomy Foundation to develop a new Bioeconomy Innovation and Piloting Facility at the Lisheen Bioeconomy Campus. The facility, due for completion in Q1 2019, will stimulate the scale-up of technologies from industry and academia; enabling the valorisation of side-streams and residues from agri, food, marine and other sectors. In 2018, the Lisheen Campus also became home to the AgriChemWhey project, a €22 million Biobased Industries Joint Undertaking flagship initiative. The project led by Glanbia, aims to develop the world's first integrated biorefinery for converting food-processing residues to bio-based chemicals. The project is focused on the conversion of by-products of whey protein manufacture from the dairy sector, including whey permeate and delactosed whey permeate into added-value products – specifically L-Lactic acid, polylactic acid, minerals for human nutrition and bio-based fertiliser.

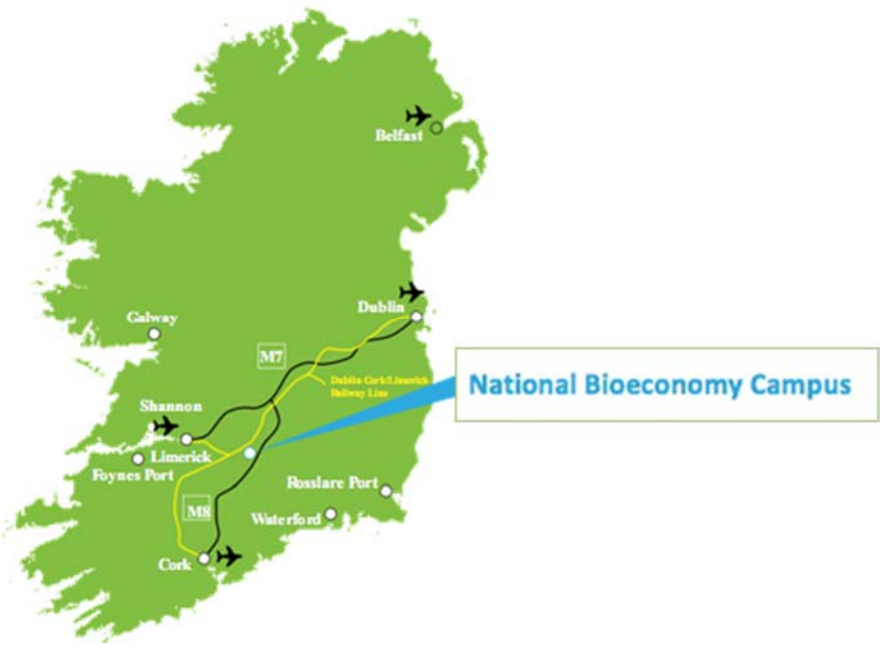

Figure 1. Ireland's National Bioeconomy Campus at Lisheen Co. Tipperary [1]

In 2018, the Irish Government published its National Bioeconomy Policy Statement, highlighting the potential of the bioeconomy in supporting Irelands transition to a low carbon competitive economy. The Policy highlights the Lisheen campus among Irelands most significant bioeconomy developments and notes as a key action, the translation of research into real world applications through promoting collaboration between research institutions (academia) and industry through use of piloting/demonstrations via the Lisheen campus [2].

Andalusia is the most populous region of Spain (8.4 million inhabitants) as well as one of the largest in Europe (87,268 km^2). In spite of the current economic challenges, the recent attention for the Circular Economy on European (including Biobased Economy) is becoming the driver for new growth, as Andalusia is uniquely positioned for a transition towards a more circular and biobased economy.

Figure 2. Model Demonstrator Region of Andalusia, Spain

One of the reasons for Andalusia's unique position is that it features a large agricultural sector. Over 44,3% [4] of its surface area and 8,4% [5] of its work-force are dedicated to this sector, and Andalusia's agri-food industry is one of the main economic drivers of the region. It is extended all over the Andalusian area and is widely present in rural areas. The biomass resources are coming mainly from olive grove, as well as the fruit and vegetable sector (Andalusia is the world's largest olive producing region and home to a substantial horticultural sector producing fruits and vegetables). Also, there are several initiatives related to microalgae cost-effective cultures in Andalusia, based on the high sun radiation of the region, average potential radiation of 4.6±0.3 kW h/m^2 per day [6] (algae can provide a means to convert sun light and CO_2 into valuable chemicals). Andalusia gets a total solar radiation of 4,75 kWh/m^2 per day. The high intensity of irradiance, together with the wide area of the region, 87.597 km^2, makes Andalusia the Spanish region with the highest solar potential [7].

Regarding biomass current use, Andalusia has a strong bio-energy sector and is at the forefront of thermal biomass in Spain with almost 24.000 small installations and 11 large scale operational biofuel plants with a capacity of 1.280 ktons/year. The region is the Spanish national leader in bio-fuels production. In addition, Andalusia has 18 biomass fueled power plants with a total installed capacity of 257 MW and 17 biogas facilities with almost 30 MW capacity sourcing their gas from landfills and wastewater treatment plants. Moreover, both the olive industry and other agri-food industries are already acting as bio-industries valorizing (by-)products to produce feed, fertilizers, energy and

composting. However, it is the progress to advanced integrated biorefineries which could further strengthen Andalusia's position in the Biobased Economy.

Having this interesting background, the Andalusian Government has promoted the development of the Andalusian Circular Bioeconomy Strategy (which is expected to be approved in the next few months), as a proof of its commitment with this opportunity. This document defines main objectives and actions to be conducted in the following years, in order to make the most out of regional assets.

2 Regional baseline

2.1 Value chains considered

Building new value chains based on the development of sustainable biomass collection and supply systems remains a priority issue for BioBased Economy development. A value chain involves all the actions and activities that must be executed to get from a feedstock till a ready market product. Each step in the value chain must add value, so the final consumer/client will be interested in paying and increasing amount of money for the product or service in proportion to its progress along the value chain. Cross-sectoral value chains involving industries from a diversity of traditional sectors are usually required to build value chains for Biobased Economy.

ICT-BIOCHAIN will consider bioeconomy value chains related to biomass and will focus on logistics aspects and how these could be improved by using ICT tools. The following picture, produced by VTT (part of project consortium), provides information of the main elements to be considered in the afore mentioned value chains.

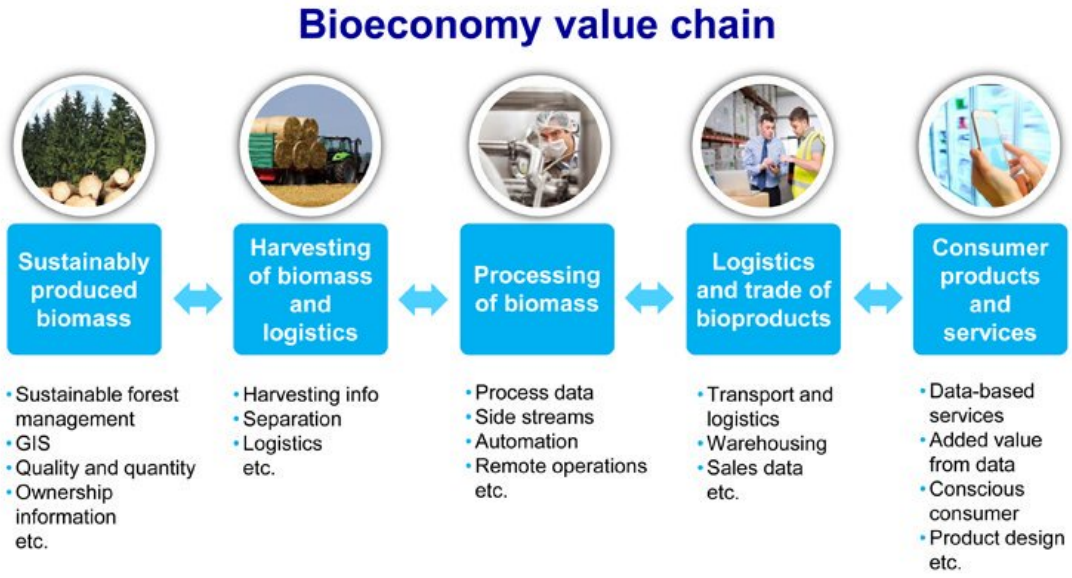

Figure 3. Bioeconomy value chain concept considered in ICT-BIOCHAIN project

Different biomass feedstock has been identified in each region and their corresponding value chains and current status are presented next.

2.1.1 South-East Ireland

Parts of the Irish Model Demonstrator Region (MDR) circle contains some of the richest agricultural land in Ireland and the world [8]. Ireland's biological sectors are responsible for significant employment, producing substantial volumes of outputs with formidable financial value, and playing a role in feeding an ever-growing global population. The agri-food industry (incorporating fisheries and forestry) employs over 8% of the national workforce, is responsible for 7.6% of total gross value added, and produces exports worth more than €10 billion annually. The areas surrounding the Lisheen Campus include large agri-food and forestry industry players. The headquarters for Glanbia, an agri-food multinational with revenues of €3.6 billion, is located within a 20km radius of the campus. The company is Ireland's leading dairy company, annually processing 2 billion litres of milk (40% of total national output). Other significant regional agri-food processors include; cider-producer Bulmers, meat groups Rosderra and ABP meats and dairy co-operatives Tipperary and Arrabawn. The MDR also see significant on-farm arisings of animal wastes, with an estimated 2.1 million tonnes of slurries and manures produced annually from cattle, sheep, pigs and poultry in the areas surrounding the MDR.

The bioeconomy offers opportunities for greater resource recovery from the agri-food and forestry processing sectors and to underpin both the economic and environmental sustainability of production, through valorisation of waste streams. The residues which arise from such processing include whey residues from cheese or casein production, dairy fat from milk processing, spent mushroom compost and stalk cut-offs from mushroom production, various sludges from wastewater treatment, food crop residues from apple, potato, and other food processing, lignocellulose from the wood processing sector, spent grains from the brewing and distilling industry, animal by-product from meat processing, and manures from the livestock sector.

2.1.1.1 Dairy and Residues (Whey)

In 2017 Ireland was home to some 18,000 dairy farmers, with an average herd size of 80 cows producing on average 370,000 litres of milk annually. Ireland's dairy sector has expanded considerably since the abolition of milk quotas in 2015, rising from 6,653.9 million litres of milk in 2016 to 7,268 million in 2017 an increase of 9.2% year on year. On a per county level, Tipperary, the home of the Lisheen Bioeconomy Campus has some of the highest numbers of dairy cows in Ireland. Within the Model Demonstrator Region, the Irish Cattle Breeding Federation indicates the following cattle numbers per county:

- Tipperary: 161,921 units
- Waterford: 78,562 units
- Kilkenny: 82,293 units
- Wexford: 70,304 units
- Carlow: 14,808 units

Fourteen milk processors are engaged in milk collection and processing in Ireland with three processors accounting for 68% of the national milk quota pool. Two of the largest processors, Glanbia (2.4 billion litres) and Dairygold (1.3 billion litres) are located in close

proximity to the Model Demonstrator Region, while Tipp Co-op (300 million litres) and Arrabawn (361 million litres) are both located within County Tipperary.

There was an average of 1.7 million tonnes of whey arising from cheese production in the Irish dairy sector in 2013/2014. Whey is the liquid remaining after milk has been curdled and strained for the production of cheese and is composed of water, lactose, whey proteins like α-lactalbumin, β-lactoglobulin, serum albumin, immunoglobulins, and proteose-peptones minerals and traces of fat. Whey wastewater is usually a high polluting effluent that contains significant quantities of organic matter, namely proteins, simple sugars, fat, and other organic compounds. The COD values of whey vary between 50-70 g/L, which is approximately 10 times higher than typical COD values of municipal wastewater streams. Whey proteins constitute 20% of the proteins found in cow's milk (the other 80% being casein protein). The protein fraction of whey can be isolated further to products with greater added value including whey powder (13% protein), whey protein concentrates with 35/80% protein, whey protein isolate with 90% protein or demineralized whey for use in infant formula production.

Currently, the majority of the whey, almost 60%, is valorised into many different products inside the dairy industry or by other whey processing facilities. Irish companies like Glanbia and Carbery for example are leaders in the production of whey protein products. Whey Permeate is a high lactose (up to 85%) bulking agent and flavouring ingredient produced through the removal of protein and other solids from whey via ultrafiltration. The lactose stream of whey permeate can also be used in the bioeconomy as an input for biofuels or biobased product applications. In 2018, the Lisheen Campus became home to the BBI JU Flagship AgriChemWhey project which will scale up (from 75 tonnes to 20,000 tonnes of lactic acid per annum) the production of chemical building block lactic acid from whey permeate. Sidestreams arising from the process along with delactosed whey permeate will be valorised for agricultural use and human nutrition. Meanwhile, Irish dairy cooperative, Carbery at Balineen in Cork, focus on whey derived ethanol, where the lactose stream is fermented and distilled to produce 10.5 million litres of high purity bioethanol/annum, which can be used as biofuel in the transport sector where it is 85% less carbon intensive than petrol. The Dairygold Cooperative Society of Ireland in Michelstown, treat dairy wastewater through anaerobic digestion to generate biogas, saving more than 1,900 tonnes of carbon dioxide emissions in 2013.

The following table provides information of some of the main national initiatives initiatives related to adding value to whey and it's components.

Regional entity involved	Initiative/project name	Funding
Glanbia, University College Dublin, Commercial Mushroom Producers, Trinity College Dublin, Teagasc, Tipperary County Council	AgriChemWhey - An integrated biorefinery for the conversion of dairy side streams to high value bio-based chemicals	European - Biobased Industries Joint Undertaking

IRIS Advanced Engineering, Dunreidy Engineering Ltd.	WHEYLAYER -Whey protein-coated plastic films to replace expensive polymers and increase recyclability	European – FP7
University College Cork, Environmental Protection Agency	NEWTRIENTS – Novel Eco-Sensitive Wastewater Treatment Recovering Dairy Industry Effluent Nutrients	National - Environmental Protection Agency, Ireland
Glanbia, Carbery, Dairygold, Kerry Group, University of Limerick, University College Dublin, University College Cork, Dublin City University	Pre-commercial Scale-up of Biologically Active Milk Protein Hydrolysates	National – Enterprise Ireland
Dublin Institute of Technology	WHEYSAN - Natural whey-based disinfection formula: a solution for the sanitizing of whole and fresh-cut fruits and vegetables	European –FP7
Dublin City University University College Dublin University College Cork University of Limerick Carbery Dairygold Glanbia Kerry	Mining for milk-based bio-actives using microbial fermentations	National – Enterprise Ireland

2.1.1.2 *Lignocellulose*

Forestry accounts for 10.7% of Ireland's land area or 750,000 hectares. The government has set a target of achieving a productive forest area of 1.2 million ha by 2030, or 17% of the land area. State owned company Coillte have managed 70% of national forestry in recent years, although the figure is declining due to maturing farm forestry production. Irish forestry industry contributes about €2.1 billion to the Irish economy and provides approximately 12,000 jobs in rural areas of Ireland. In 2015, 78% of Ireland's forest products were exported at a value of €355million. In Ireland, the forest sector is primarily focused on construction products – sawn timber and panel products. Currently there are 8 large sawmills operational in Ireland processing over 90% of Irish sawmilling output. Two of these large sawmills, Glennons and GP Wood are based in Cork. There are also three large panel board plants in the country. Two of these plants are owned by Coillte and are located within the Lisheen Model Demonstrator Region, namely Medite based in Clonmel Co. Tipperary which produces Medium Density Fibreboard (production capacity 410,000 m3), and Smartply (capacity 350,000m3) in Kilkenny producing Oriented Strand Board [9].

With 3.01 million cubic metres of softwood roundwood processed Ireland in 2015, 1,000,000 sawmill residues were produced including bark (138,000 tonnes), sawdust

(256,000 tonnes) and woodchip (606,000 tonnes) for uses including renewable energy and mulch [5]. Wood biomass provides approximately 25% of Ireland's renewable energy and approximately 1.4 million m^3 is combusted to produce energy annually [10]. Additional forestry materials including brash and bark can be difficult to mobilise and are often left unharvested. Logistical challenges around forestry biomass include collection limitations, limited knowledge on site impacts and transportation of low density residues. In Ireland, spruce is the most abundant tree species and it produces approximately twice the amount of forest residues compared to pine and birch due to its long crown. It has been estimated that, with Sitka spruce (Picea sitchensis) harvested down to a diameter of 70 mm, forest residues (including needles) after clearfelling constitute about 30% of total above ground biomass.

Other potential lignocellulose feedstock sources include straw arisings in Ireland's cereal sector (primarily wheat and barley). For each 100 kg of harvest cereals, between 120 and 260 kg of straw is generated, depending on the type of crop. Approximately 1.17 Million tonnes of wheat and spelt straw was produced in Ireland in 2015. The high moisture content and low energy and physical density of crop residues make their collection, harvesting, transport, storage and processing more difficult than conventional biomass. In the same year 2.1 million tonnes of barely straw was produced. Applications include compost and animal bedding. An additional estimated 500,000m^3 of recovered mixed paper is exported annually at low value, while 150,000m^3 of spent brewers grains arising from the brewing sector is primarily used as animal feed.

Lignocellulosic feedstocks consist mainly of three polymers: cellulose, hemicellulose and lignin along with smaller amounts of pectin, protein, extractives and ash. The composition of these constituents can vary depending on the source. Hardwoods contain 40-55% cellulose, 24-40% hemicellulose and 18-25% lignin. Softwoods contain 45-50% cellulose, 25-35% hemicellulose and 25-35% lignin while wheat straw contains 29-35%% cellulose, 26-32% hemicellulose and 16-21% lignin. Newspaper contains 40-55% cellulose, 25-40% hemicellulose and 18-30% lignin.

Currently lignocellulosic residues in Ireland are diverted to low value applications including bark mulch, feed and energy. The availability of sugars and lignin from lignocellulose have significant potential within the emerging Irish bioeconomy for higher value applications. Projects which demonstrate potential for producing high value products from lignocellulosic biomass are listed next.

Regional entity involved	Initiative/project name	Funding
University of Limerick, Eire Composites	LIBRE - Lignin Based Carbon Fibres for Composites	European – Biobased Industries Joint Undertaking
University of Limerick, Ecosphere Ltd.	DIBANET - The Production of Sustainable Diesel-Miscible-Biofuels from the Residues and Wastes of Europe and Latin America	European – FP7

University of Limerick	CELLULOSOMEPLUS - Boosting Lignocellulose Biomass Deconstruction with Designer Cellulosomes for Industrial Applications	European – FP7
University College Dublin, Teagasc	High value products and ethanol from wheat straw and bran: enhancing our understanding and capacity for fungal bioconversion.	National – Department of Agriculture, Food and the Marine
Teagasc, IRIS Advanced Engineering	WASTE2FUELS - Sustainable production of next generation biofuels from waste streams	European – FP7
Pure Fiber Ltd.	BioAXOS - A novel cost-efficient process to produce best-in-class prebiotics from side-products of the bioethanol industry	H2020
University of Limerick	FORBIO - Fostering Sustainable Feedstock Production for Advanced Biofuels on underutilised land in Europe	European - H2020

2.1.1.3 Horticulture

The Irish horticultural industry is an important economic sector in Ireland. The Department of Agriculture, Food and the Marine (DAFM) estimates that the sector was worth €433m (farmgate value) in 2016, making it the 4th highest sector in terms of gross agricultural commodity output value.

Ireland is the only country in Europe which includes mushrooms among its top 10 agricultural commodities. The mushroom sector is Ireland's largest horticultural sector with an estimated farm gate output value of €122m. In 2017 Ireland produced 67,000 tonnes of mushroom, down from 70,000 produced in 2016. Monaghan Mushrooms based in Co. Monaghan is the second largest producer of fresh mushrooms and the largest producer of mushroom substrate in the world, with the company's Irish operations producing some 150,000 tonnes of environmentally sustainable mushroom compost each year which is sold to mushroom growers throughout Ireland. Mushroom compost is a mixture of 60-70% straw, 28-34% poultry litter, and 2-4.5% gypsum. The Irish mushroom industry in total produces in the region of 200,000 tonnes of spent mushroom substrate (SMS) every year. SMS is a valuable source of major and minor nutrients as well as organic matter. It contains Nitrogen, Phosphorous and Potassium (NPK) as well as other elements such as Magnesium, Calcium, Manganese, Copper, Zinc and Boron and as such is of major value to the agricultural sector for soil fertility. The average moisture content of SMS has been measured as 65%, and the volatiles and ash contents, on a dry basis, are 61% and 39%, respectively [11]. SMS is a valuable material for improving soil structure in tilled soils owing to its highly organic nature and increasing dry matter production on grassland soils, with around 72 % of all SMS in Ireland applied to land. Small amounts of residues including processing offcuts are also produced from

the mushroom processing industry. Commercial Mushroom Producers, a mushroom cooperative established in 1999. and today Ireland's sole Mushroom Producer Organization represents over 90% of Irish Mushroom producers and growers, including in the areas around Lisheen. While mushroom residues are currently used in low value applications, ongoing BBI JU initiatives involving Irish organisations show significant opportunities for developing innovative new products including platform chemicals and nanocapsules (please see table below).

The total tonnage of culinary, dessert and cider apples harvested in 2011 was 17,650 tonnes. Cider apple sales tonnage (for dedicated cider varieties) was 4,821 tonnes in 2011. Dessert and cider apple varieties are grown principally in the counties around the Lisheen campus, notably Waterford, Kilkenny and Tipperary. Apple pomace is a major by-product of the apple industry representing twenty-five percent of the fruit weight (approximately seventy-five percent of the fruit weight is extracted as juice. Approximately 3,000 tonnes of apple pomace were estimated to be produced per year in Ireland between 2010-2013. The largest producer of apple by-products is the Irish cider industry, followed by smaller artisan producers. Within the Model Demonstrator Region, significant quantities of apples are processed at the Bulmers cider plant in Clonmel which produces 135 million litres of Irish cider annually from 25,000 tonnes of apples. Apple pomace can be a good source of phytochemicals primarily phenolic acids and flavonoids. Current common applications of apple pomace are the direct disposal to soil in a landfill and recovery of pectin (gelling agent, stabiliser, and source of dietary fibre). Other fruit industry residues include smaller amounts arising from the peach processing industry including 250 tonnes of peach kernel, 3,230 m3 of peach processing water and 56 tonnes of peach pomace produced in 2013.

Initiatives which demonstrate potential for producing high value products from mushrooms, fruit and other horticultural sources and residues include:

Regional entity involved	Initiative/project name	Funding
Monaghan Mushrooms	FUNGUSCHAIN - Valorisation of mushroom offcuts to obtain high value products	EU – Biobased Industries Joint Undertaking
Monaghan Mushrooms, Celignis	BIOrescue - Enhanced bioconversion of agricultural residues through cascading use	EU – Biobased Industries Joint Under
Glanbia, University College Dublin, Commercial Mushroom Producers, Trinity College Dublin, Teagasc, Tipperary County Council	AgriChemWhey - An integrated biorefinery for the conversion of dairy side streams to high value bio-based chemicals	European - Biobased Industries Joint Undertaking
University College Dublin, National University of Ireland	Recovery of functional components from by-products of fruit, vegetable and fish processing	National – Department of

Galway, Dublin Institute of Technology, Teagasc		Agriculture, Food and the Marine
Teagasc, University College Cork, Largo Foods	Potato Peels: a Rich Source of Pharmaceuticals and Bioactives	National – Department of Agriculture, Food and the Marine
Shannon ABC	From Plants to Products – Bioactives in Specific Plant Species	National – Enterprise Ireland
University College Dublin	AGRIMAX - Agri and food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technologies for new high added value applications	European- Biobased Industries Joint Undertaking
Shannon ABC	Fruit processing: turning waste streams into revenue streams	National – Enterprise Ireland

2.1.1.4 Animal Manures

Ireland sees large arisings of residues produced from the cattle, poultry and pig production sectors in the form of manures and slurries. In 2003 the national cattle herd of 6.3 million animals produced 37 million tonnes of manure over the winter housing period, 29.3 million tonnes (t) of which was slurry with the remainder as solid manure. With the national herd now significantly higher than at 2003, it is expected that volumes of available manures are also considerably higher. In 2015, the estimated cattle manure arisings in Ireland were 64,864,523 tonnes of which dairy manure was 21,698,075. Cattle manure is more than 90% water and when collected and is usually mixed with other organic materials such as bedding material, straws etc. The composition of animal excreta is a complex issue, and is dependent on the class of animal, diet, digestibility of food, bedding, and stage of growth, among other factors. Total sugars content of cattle varies between 33% and 39% for the cattle excreta (with cellulose as the major polysaccharide in Dairy slurries), with significant levels of ash and extractives. Cattle slurry and manure are typically landspread during spring and summer months, while in winter are prohibited from being spread and are stored until the following spring in order to comply with the European Union's Nitrates Directive.

Approximately 898,000 tonnes of chicken manure were produced in Ireland in 2015. The value of manure as a source of plant nutrients has long been recognized, and poultry manure is a concentrated plant food containing two to three times as much nitrogen, three to five times as much phosphorus, and about the same amount of potassium as other farm manures along with properties which help to increase the soil's moisture-holding and nutrient-holding capacities. Chicken litter has a much lower moisture content than pig or cattle excreta, between 20 and 50%, depending on husbandry practices [(7)].

In 2015, an estimated 1,843,175 tonnes of pig manure were produced from close to 1.5 million pigs in Ireland. In fresh pig manure, moisture content can reach up to 90% wt and may also contain other organic materials such as bedding material, straws, etc. Pig

manure slurry contains 21% and 46% total sugars (primarily hemicellulose) with significant levels of ash and extractives [7].

While largely landspread, some manures and slurries are co-digested with other feedstocks in biogas plants across Ireland. Biogas yields following anaerobic digestion can also be improved when materials are mixed, such as combining manure with crops or fruit and vegetable waste to ensure the ideal carbon to nitrogen ratio for digestion is achieved. Plants that utilize manures in biogas or biomethane production include Green Generation (pig manure) at Nurney, Co. Kildare, participants in Ireland's first Renewable Gas grid injection project. The GreenGas AD Plant, in Co. Limerick, utilizes dairy manure and poultry litter from the plants farm to produce biogas in co-digestion for CHP production. The solid residual material which remains after anaerobic digestion is nutrient-rich and can be used as a fertiliser, replacing synthetic fertilisers and/or soil conditioners. The nutrient content, while dependent on the nature of the feedstock contains important plant nutrients including nitrogen, phosphorous, potassium, magnesium, sulphur, and trace elements in a more available form compared with the undigested materials. BHSL in Co. Limerick has developed an innovative approach to valorising chicken litter, using a miniaturized fluidized bed combustion system to produce heat and steam for on-farm use, and creating an optimized growing environment in chicken houses.

Other projects which aim to optimize the potential of manures in the bioeconomy are listed next.

Regional entity involved	Initiative/project name	Funding
University College Dublin, Carton Bros, National University of Ireland, Maynooth	AGROCYCLE - Sustainable techno-economic solutions for the agricultural value chain	European – H2020
Ashleigh Farmers (Environmental) Ltd, Gilmore & Clarke Electrical	BIOWAVE - Upscale and demonstration of an integrated novel microwave pre-treatment system for efficient production of biogas from anaerobic digestion of pig manure to create a sustainable waste management system	European – H2020
BHSL-Hydro, Irish Farmers Association,Mercury Consulting, Ireland	SUPPER - SUstainable Poultry Production thru' Environmental Recycling	EU – Eco-Innovation

2.1.2 Andalusia

Andalusia has a strong feedstock position at European level, although its use and exploitation has various levels of maturity. Nevertheless, all of them have a great potential for innovative biobased and circular investments which could lead to the

creation of new value chains. The main feedstock-driven value chains in which significant investment is expected are the following:

- ***Horticulture and agri-food***. In this value chain, significant investment is expected, particularly at demo level. It is likely that by 2025 at least 3 new commercial scale plants using these feedstocks will be operational in Andalusia.
- ***Olive sector***. Some innovative commercial scale plants are already operational in this value chain and at least 2 more are expected up till 2025.
- ***Forestry.*** This feedstock is currently used mainly for energy purposes but could be used for the production of biobased chemicals in the future.
- *Livestock farming*. Several commercial scale plants have been built for the production of fertilizers and biogas. Given the higher TRL of the associated technologies, between 10-20 more are expected up till 2025.
- *CO_2 as feedstock for algae cultivation*. Andalusia's great potential for growing algae, together with its strong position in terms of algae cultivation technology, should be able to result in 2 commercial scale plants.

From these value chains, olive sector and algae have been chosen as they represent a mature and a novel value chain respectively. This creates a great opportunity for knowledge transfer in the region, for re-digitising the olive sector and for creating and boosting business activities related to algae. Vegetable wastes value chain has been selected to cover part of the horticulture sector (including subtropical fruticulture) and forest, ensuring this way a good ICT-BIOCHAIN coverage of the region.

2.1.2.1 Olive and olive oil waste

The olive sector in the Andalusian economy is one of the most important in terms of extension, economic value, generated biomass, employment and related direct and indirect industry. Andalusia is the main producing region of olive products worldwide, with an agro-industrial network composed of 800 mills, 16 olive oil refineries, 211 seasoning plants and 40 plants for the extraction of pomace oil. The average olive production is 5.48 tons of olives, which is mainly intended to obtain olive oil (92%) and the rest to table olive. The agri-food industries in this sector generate a high quantity of by-products as a result of their activity as the following picture shows.

The pomace that is generated in the production of olive oil is mainly intended to obtain olive oil but can also to produce electricity. The pomace contains fat, that is extracted to obtain olive oil pomace, so it is necessary to dry and extract. The result is the olive pomace oil and a product, olive marc ('orujillo') with good properties as fuel and properties that allow its use in the generation of thermal or electric energy. The average production of 'orujillo' in Andalusia is around 985,500 tons per year.

Another by-product obtained is the olive stone or olive pit, which is a fuel of optimal characteristics for thermal applications in households. 277,000 tons of olives stone per year from the oil industries and 80,000 tons from the seasoning olives industries, are produced in Andalusia. Many other potential bioproducts of interest, like fibers, are nut in the olive stone. Finally, more than 2.5 million tons of remains of pruning, are generated

annually. Specific equipment for chipping and management of this material is actually being developed.

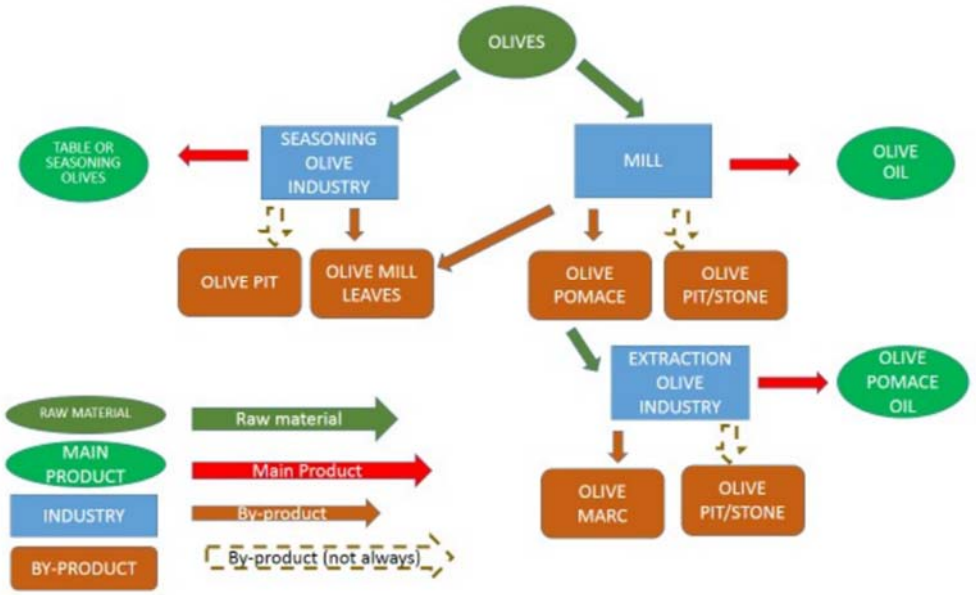

Figure 4. Andalusian olive oil production value chain

The total energy potential of the olive by-products in agro-industries of the olive grove is estimated in 567.702 tep/year. These by-products are mainly used for energy purposes; in particular, 47,0% of the total amount generated is used for electricity generation or cogeneration and 32.9% for thermal applications. Altogether energy uses represent 79.9% valorization of the total produced by-products. Their incorporation as soil organic matter accounts for 14.3%, while the rest of applications (animal feed, residue management, …) represent 5.9% used for refining olive oils and to develop more added value byproducts.

At the other end of the spectrum, there are applications oriented to the development of new added value bioproducts (anti-oxidant food ingredients, lubricants, cosmetics and bioplastics), which are the most innovative and promising ones. There are some companies but especially many research projects in preliminary phases, and alliances/contracts between research centres and businesses making significant progress in these fields. As an example, Natac-Innovaoleo is a joint venture between Oleícola 'El Tejar' and Natac. The company has set up a biorefinery for olive oil waste streams, which produces nutraceuticals and some side-streams, which could be used to obtain other biobased products. Their business model allows a complete in situ integration in a conventional plant of an advanced biorefinery which significantly increases the profitability of their production. Neolbio has developed a number of conversion routes for both lignocellulosic vegetal waste and oils/fats (including glycerin) towards several products like microbial oils and biopolymers although it is no longer operating. Formulaciones is a company producing polyurethanes by using olive oil and fatty waste streams as feedstock. Olive sector cooperatives are also very active. Oleoestepa is an

agricultural cooperative executing a project focused on olive oil press residues valorization into nutritional products of high added value, while San Isidro de Loja, another cooperative, is leading a project to convert waste streams from the olive oil refinery into compost and vermicompost. Seneca Green Catalyst has a project to obtain high added value products for the cosmetic industry from fatty streams. Finally, Elayo group has developed two industrial lines for valuable compounds extraction that will be later used by food, pharma, diet and cosmetic industries, together with new materials production starting from olive pit and bio-resins.

The following table provides information about main relevant R&D projects focussed on olive wastes valorisation.

Regional entity involved	Initiative/project name	Funding
Jaen University	Design and optimization of a sustainable biorefinery based on olive biomass and the olive oil industry: techno-economic and environmental analysis	National
Granada University	Operative Group 'Circular agro-innovation': Integral valorisation of waste for a sustainable olive sector	European (Rural Development Programme)
Cordoba University	Nutradaf: Olive Oil functional fractions characterization, new products formulation and analysis of their effects on health	European
Pablo de Olavide University	Sustainable management of olive industry	Regional

2.1.2.2 Vegetable waste

Vegetable waste has considerable importance in Andalusia, the most relevant example relay on Almeria province which is, together with The Netherlands, the main area of fruit and vegetables production in Europe. Almeria's production reaches 3 million Tons/year, with a value of its agricultural production being close to 2,000 million €/year. Its cropped greenhouse area is about 30,000 Ha. The 80% of the production is exported to different European countries. Residual biomass from plastic covered horticulture is 1.750.000 MT/year of wet weight and 235.000 MT/year of dry weight, which means and estimated amount of 94.000 MT/year of carbohydrates, 47.000 MT/year of protein, 23.500 MT/year of lipids and 707 MT/year of lignin. Regarding horticulture and forestry waste streams, there is so very important potential for biobased industry development, although currently major efforts are focused on composting for fertilizers, animal feeding, anaerobic digestion for biogas or incineration for bioenergy. Regarding woody biomass, uses by now focuses on a double application: either for timber products (sawlogs, boards,

chipboard, etc), or for energy use (electrical or thermal energy production). In the first case, the residual fraction of the main forestal use can also be used for energy production.

To make these applications more effective will be necessary technological improvements, development of new processes, advances in logistics and new infrastructures that allow an adequate profitability and utilization of resources from chemical and biological processes. The Andalusian Government has presented various lines of action on management of plant debris in horticulture from the perspective of circular economy. These actions will be included in the Action Plan of the Andalusian Bioeconomy Strategy. The consumption of biomass transformed as livestock feed or fertilizer in soils has great possibilities in Andalusia, given the importance of the agricultural sector and its climate of dry periods, which does not allow the use of pastures year-round.

Currently, the energy use does not enable biomass fractionation to obtain recoverable products and this results in an economic sub optimal valorization of these streams. An advance in the fractionation of the biomass to improve its recovery is needed.

Within this value chain, the following investments and activities are being carried out by main stakeholders. Fertiberia, a fertilizer producer, aims to set up a commercial scale plant for the recovery of nutrients from both solid and liquid waste streams, including vegetal waste streams. Biomasa del Guadalquivir aims to set up a project which converts vegetal waste into bioethanol and other bioproducts. The project will use conversion technology by the companies Imecal and Biopolis and comprises a consortium covering most of the value chain. Ecowas also aims to set up a demo plant for the conversion organic waste into bio-ethanol. The remaining HighQuality Organic Matter (HQOM) fraction can be applied for the production of biogas, sugar syrup, chemicals (Butanol, Jet-Fuel), bioplastics and land restoration. Moreover, Natac Innovaoleo has established a joint venture Alvinat together with the winery Alvinesa which operates a biorefinery for wineyard waste streams which produces nutraceuticals. Formulaciones is producing polyurethanes and is able to use forestry waste streams as feedstock. Bodegas Robles has demonstrated a anaerobic digestion process for winery residues, which produces biogas and a fraction which can be converted into compost. Fomento de la Biomasa y Cogeneración (FBC) is a technology developer of a pyrolytic process, which can be used to convert plastics and biomass into a gaseous fraction, a solid fraction (to be used as fertilizer) and a liquid fraction (to be used as biofuel or insecticide). Agrícola El Bosque is a blackberry producer, which aims to valorise its biomass towards higher added value applications. The biomass is rich in antioxidants and as such has a high potential for applications in cosmetics and pharma. Frutilados del Poniente is a cooperative of 21 fruit growing companies performing a project focused on the conversion of fruit waste into animal feed. Arsinger is an engineering company which designs industrial plants at demonstration scale. They have a project for converting agricultural waste streams into active carbon. Finally, Seneca Green Catalyst, as a technology supplier, has a technology for producing biobased compounds from the agricultural and energy sector based on biocatalysis while Rioma, has developed a process for the production of pigments of interest of the textile sector and resins for furniture built using vegetal and forestal waste.

The following table provides information about the main national and international initiatives related to vegetable waste.

Regional entity involved	Initiative/project name	Funding
Factorverde	New models for supply and logistics platforms of biomass	National
Almeria University	SABANA – develops a large-scale integrated microalgae-based biorefinery for the production of bio stimulants, biopesticides and feed additives, in addition to biofertilizers and aquafeed, using only marine water and nutrients from wastewater	European
Alhondiga 'La Unión'	BIOVEGE- development of bioplastics (meshes and films) and bioactive ingredients with high added value for agri-industry from horticultural by-products generated in the Andalusian horticulture areas	National

2.1.2.3 Algae

Andalusia's great potential for growing algae, together with its strong position in terms of algae cultivation technology, is making the region to gain an interesting international position. Several promising projects are on-going using algae for waste water and CO_2 emissions treatment facilities, contributing to the development of the concept of an algae biorefinery, under which multiple high value-added products (food, nutraceutical, energy, materials, services) in a single installation can be obtained. In addition, more advanced biobased projects for the production of bioplastics and the production of high added value chemicals are on-going in which partners from the region play an important role. The establishment of new links between algae cultivation and the extraction of valuable chemicals (which is now mostly taking place based on olive oil by-products) may yet give another boost to the establishment of algae biorefineries. This way, cost-effective algae cultures are a promising feedstock and a huge opportunity for high quality proteins and bioactive compounds production causing relevant progresses.

Algaenergy has really advanced algae cultivation technology and is already processing CO_2 from the energy sector. It has demonstrated the production of biofuels, fertilizer, food ingredients and cosmetics. Its technology is really advanced (TRL 8) and as such Algaenergy is very close to setting up a commercial scale plant.

The following table provides information of main international initiatives related to algae.

Regional entity involved	Initiative/project name	Funding
Huelva University (Spain)	MIRACLES - developed integrated, multiple-product biorefinery technologies for the production of specialties from microalgae for application in food, aquaculture and non-food products	European
Andalusian Energy Agency	CO2ALGAEFIX -aimed at the development of biofixation of CO_2 from industrially emitted real flue gases by microalgae culturing, and the transformation of such gases into products of commercial interest	European
Institute of Agricultural and Fishing Research and Training (IFAPA)	SOLEALGAE - Transcriptomic evaluation of functional compounds based on microalgae and development of new genomic analysis tools that drive aquaculture of sole	Regional

3 Use of ICT, IoT, Industry 4.0 in considered value chains

The use of Big Data techniques and cognitive technologies are deeply related to the development of different technologies allowing the collection of data from very valuable information sources. The rapid development of the Internet of Things (IoT) has given new perspectives for the improvement of biomass logistics with the emergence of technology applications and biomass logistics management systems. This applies, particularly, along biomass pre-treatment, distribution and sale of condition-sensitive products. Achieving the objectives, for instance, biomass quality partly relies on physical traceability throughout the supply chain. Track and trace applications from the field or production site through the chain and in the processing environments can lead to effective identification and traceability in the whole supply chain. In March 2015, the European Commission launched the creation of the Alliance for the Internet of Things, where a working group about agriculture and smart food security is participating, having a component on biomass. The IoT makes possible cooperation between producers, logistics and transportation services providers and hospitality and retail companies that can work together to ensure efficient delivery of higher quality biomass.

3.1.1 South-East Ireland

3.1.1.1 Dairy and Residues (Whey)

ICT-Technologies are already imbedded within the Irish Dairy Sector at various levels. The COREmilk software system for example is used by 70% of Irish co-operatives allowing

efficient management of key business aspects, including milk collection, farmer payments, liquid milk distribution and the management of financial accounts and reports [12]. Information collated in the COREmilk system can be shared with farmers. An app developed by COREmilk called "MilkedIn" allows milk suppliers access their milk data via their mobile phones or tablet. Suppliers can see all of their current and historical milk collections, tests and financial details.

The RT10 smartphone device is currently being used by a number of Irish farmers to analyse the somatic cell count (SCC) of milk, and determine different types of infection, including E coli, Staph aureus, or any other common causes of mastitis. Since going live in February 2014, Herdwatch has over 5,000 farmers users per day supporting their farm management (without internet access) and eliminating their farm compliance paperwork [13]. Sabermilk is new automated milk sensor from New Zealand that allows Irish farmers to get live milking results within two minutes of cupping a cow. The sensor allows real-time results for yield, fat, protein, lactose and conductivity, as well as plant performance monitoring. Another product being used, Heatime, is a new long-distance stand-alone heat detection system enabling dairy farmers to improve the heat detection across the herd. Based around behaviour, movement and activity, a tag embedded with sensors fitted to the cows collar identifies changes in normal activity and behaviour around estrus and detects heat activity with individual cow records accessible remotely by smartphone through a touchscreen system [14]. Tyndall National Institute in collaboration with Teagasc are using nanotechnology to develop a cost-efficient nanowire chip sensor, to provide on-site disease testing (IBR, Liverfluke) in cows within 15 minutes. PastureBaseIreland, meanwhile is a grassland management decision support tool and a mechanism to capture background data on farms, including quantification of grass growth and dry matter production (total and seasonal) across different enterprises, grassland management systems, regions, and soil type [15]. Automation has also helped to improve the efficiency of Ireland's dairy sector. Teagasc estimates that there were approximately 500 automatic milking setups in Ireland (North and South) in 2015 with Irish companies like Pearson Milk Technologies and Dairymaster leading the way in the development of robotic milking equipment and milking parlours.

Further research in the field of IoT, ICT and Industry 4.0 technology applications within the dairy sector is ongoing. Vistamilk, a recently announced Research Centre of Excellence marks a collaboration between agri-food and ICT institutes in the development of precision-based dairying while Dairymaster, Institute of Technology, Tralee and Lero recently joined forces to investigate new Internet of Things and Artificial Intelligence technology approaches to improving dairy efficiency.

3.1.1.2 Lignocellulose

The potential of ICT technologies to improve the efficiency of lignocellulosic value chains is already being realized in Ireland's forestry and wood processing sectors. Coillte who manage over half of Irish forestry have been leading the way in integration of ICT technologies to improve the efficiency of their forestry operations. In 2017 Coillte integrated Treemetric's, Forest HQ platform into their operations. The cloud-based forest management platform offers realtime, centralised visibility and communications for essential forestry processes [16]. The Forest HQ platform encompasses a number of different technology modules, which work collectively to capture, analyse and interpret forestry data and information remotely. Coillte also use specialised software and planning technologies, provided by Remsoft which use algorithms to strategically create plans for Coillte forests spread out over two growing rotations (typically 80 years in Ireland), to help forest managers plan while balancing the economic, environmental and social objectives from their forests. These strategic plans are then used to create Forest Management Plans over a five-year time horizon helping managers decide on the best areas to harvest at any given time. Coillte are also integrating state-of-the-art technology to improve the efficiency of their timber haulage fleet. To improve the management of the fleet accessing Coillte forests, state-of-the-art electronic timber removal (eTRP) GPS linked software systems have been developed and installed. The eTRP platform is currently being trialed with a view to deploying an industry-first, full voiceless centralised dispatch for all of Coillte's consigned deliveries. This will result in significant haulage efficiencies, lowering overall fleet travel and reduction in carbon footprint. Coillte are also currently implementing a new Forest Management System with Trimble Geographic Information System (GIS) technology at its core to allow more efficient and effective forestry management.

3.1.1.3 Horticulture

The mushroom production and processing sector has increased efficiency in Ireland over the last decade through integration of technology with Monaghan Mushrooms at the forefront of developments. In 2010 Monaghan Mushrooms opened a new state-of-the-art production facility built by associate Tyholland Mushrooms, with 8 individual mushroom growing houses, each equipped with the latest technology used in mushroom production, including energy-efficient geothermal heating, cooling and humidification systems to guarantee a consistently high quality of product. Inside each of the houses, compost is distributed automatically on to a fully automated system of racking which, if laid end to end, would span a distance of 15kms [17]. Automated hydraulic trolleys enhance the picking process and reduce the time taken to prepare the product for delivery thereby ensuring that customers will be guaranteed fresher, better quality product. The growing houses together provide a total growing area of 21,306 square metres. Carlow's Codd mushrooms are another leading Irish mushroom grower, producing 5,000 tonnes annually. At Codd Mushrooms farm each growing room is

equipped with automated watering systems and a dedicated computerised harvesting IT management system which details yields, assists in forecasting and ensures traceability back to harvester [18].

3.1.1.4 *Manures/Slurries*

As agriculture begins the process of digitization, a range of innovative digital and automated technologies to improve efficiency of manure and slurry management are being made available and are being introduced by farmers. Automatic passage scrapers, for example Pearson's hydraulic scraping systems, are now being introduced on farms across Ireland. This automated slurry management system relieves the pressure on the farmer of having to manually scrape passages, leaving more time to manage the herd and farm. Technological advances are also being made to improve the land spreading of manures and slurries. As the success of slurry application is often variable, The John Deere Manure Sensing system allows farmers to more precisely apply the slurry, based on a nutrient target and limit rates in kg/ha and utilising site-specific prescription maps. With over 4,000 measurements per second the field proven HarvestLab sensor automatically controls the desired nutrient application rates maximising yield and product quality while cutting costs on mineral fertilisers. During application an NIR sensor compares actual nutrient levels with the desired target levels and automatically controls the precise application of these. The BHSL system for valorising chicken litter integrates digital technology solutions to improve process control and efficiency. The BHSL Toploader technology is a fuel handling unit whose movement and position are monitored by inbuilt sensors. A fuel demand signal is triggered by level sensors in the fuel buffer hopper, while remote operators can also view the storage area through a camera, and manually operate the Toploader or Conveyor should the need arise.

3.1.2 Andalusia

In the "Model Demonstrator Region" project is mentioned how more and more initiatives, solutions and R&D projects are appearing in Andalusia, related to the use of ICT in the agri-food and biomass sector. The so-called 'Smart Agro-technology' is expanding, referring to the digitalization of the sector from the seed or the farm up to the wholesale markets in destination by advanced traceability tools. The chains of production, transformation and commercialization are integrated at data level, making the use of scarce resources (like water, energy, nutrients, phytosanitary or zoosanitary, etc.) more efficient, reducing the environmental impact of the productive processes involved in transformation/commercialization and, as consequence, improving the profitability of the agricultural (and, also livestock) activity.

The combination of hardware devices, software and telecommunications increasingly ubiquitous and with better bandwidth, have allowed in recent years in Spain, and also in Andalusia, the development of several cutting-edge technology solutions by companies

specialized in 'Smart Agro'. These are specialized solutions in the so called 'Agriculture 4.0' covering areas such as:

- More efficient management of irrigation and fertilization by ICT advice and/or automation.
- Advance crops monitoring by using drones, satellites or sensors on farms.
- Exploiting increasing volumes of data available by advanced analytics and Big Data environments, to generate harvest forecasts or probability of incidence of pests.
- Agronomic interpretation of satellites images, drones or mobiles using artificial intelligence tools.
- Mobility support to agricultural technicians in their field tasks.
- Automatic and bidirectional data integration with agricultural machinery, which convert precision agriculture into a practical reality.
- Geolocation of the agricultural activity as a whole through GIS tools.
- Integration of information flows between farmers and their companies or cooperatives.
- Detailed traceability management from the field to the consumer.

3.1.2.1 Olive and olive oil waste

Aside from the technologies that will be later described in the vegetable waste value chain section, there are some specific solutions in the market that are being currently adopted by Andalusian olive sector.

Global Olive has the Teleoliva® platform, a set of self-developed ICT tools that monitor the industrial process of making table olives in real time and at distance. In the olive cooking process, IP cameras are integrated and controlled remotely through an internet connection and recording probes. These cameras, placed in the control post, take pictures of the olives at different moments of the cooking process and then process and monitor them in real time through specific software.

AlcuzaApp has a software that targets olive mills and connects them with the Farmer, so he can have information about the deliveries, quality of the delivered olives, and everything related to the logistics and trade process. This also supports the olive mills in retrieving information from farmers concerning growing conditions, etc.

Plagues prediction systems for olive trees are also available on the market, as for example those from EC2C.

Finally, Galpagro is another SME that has been providing solutions for farmers in Andalusia for more than 25 years.

3.1.2.2 Vegetable waste

More and more companies are emerging in the region, bringing solutions related to ICT, specially to big data and how these could be used to boost business competitiveness.

AGROSAP has several products in the market devoted to monitoring and production costs optimization. They also provide Vantage products by Trimble Agriculture, which is an

option for GPS positioning and control of tractors and machines, of doses and applications, help with water management or a better way to monitor their performance. This company also has the DroneSAP service, which is intended for agroforestry, offering a complete service to agricultural professionals to support their decision-making, from the acquisition of data, to the study of agronomic indicators such as the NDVI (Normalized Difference Vegetation Index) and the creation of prescription maps for variable application.

The afore mentioned EC2C company has developed an A.I. platform that supports the decision-making process in many different fields. Sophisticated machine-learning methodologies, proprietary association rules, and fuzzy logic algorithms are embedded into the platform. It is then able to select which features and algorithms should be used in each case, creating a standarized tool that is easily customized for real-world applications. For example, in the case of decision farming, it helps to refine efficiency and improve production capabilities as well as to control production in advance by defining fert-irrigation or pesticide plans. Most importantly, this company also provides ICT solutions for the supply chain, aiming to answer questions such as "How much product will I have available to for delivery in the following weeks?" or "Where are the biggest opportunities for additional profit in the supply chain?", allowing the biomass producer to bind his offer to demand. Regarding demand and market, the company also has among their products marketing dynamics and market forecasting solutions built upon predictive data analytics.

Hispatec has a management software, traceability, specific ERP for agri-food industry, the ERPagro. This solution is specially designed to adapt to the needs of treatment and information management in agri-food companies, developed for horticultural, cereal, oily and viticulture companies. Its field of action covers all the links of process and product of a company. From the cultivation to the final commercialization to the consumer going through the management of supplies, accounting, traceability, quality control, etc... They also have Hortisys, which emerged from a national funding R&D project. Hortisys is the technological solution that offers the exact control, at real time, of the crops state, combined with meteorological data of both greenhouse indoor and outdoor and at regional level. It includes sensor equipment and processing unit installed in the crop, weather stations outside the greenhouse and access to data from the national public network to know the local climate and decision support software "DSS" that processes the data (and "learns" over time), converting them into helping information to take the correct measurements.

Precision farming is also addressed by Bynse, providers of sensors and Digital Crop Care, a digital service to help the farmer make better decisions about the current and future needs of their crops, based on the collection and processing of agro-meteorological data and observations in the field. Management aspects are included and it provides access in real time of all production processes (the flow of data), their relationships and critical points, management indicators that reflect reality, comparing operatives and KPIs in different time axes (agronomic, campaign, market, real) and against different processes

(operations in the field, climate effect, market effect, etc.), access to customized models of production prediction, results, resources, profitability, market impact, prices, etc. Other product they offer is Smart Pivot, which allows connecting pivots to the Internet, through Wi-Fi or mobile telephony, so they can be remotely controlled from a Smartphone or PC. Smart Pivot also allows using the intelligence and services of the Big Data platform, such as the identification of necessary irrigation doses, through meteorological and crop analysis, and automatic reprogramming.

Soltel is an Andalusian IT group with several products and services in Smart Agri sector. They have recently launched a product called SACROPS which is a system for the automated detection of plagues and diseases, performance prediction and determination of fruit maturity in olive tree cultivation. By means of the combination of different remote sensing techniques (involving temperature, humidity and pressure measures) and a platform based on the hyperspectral technology, the system can detect target substances on the plants surfaces. The analysis of the hyperspectral images provides also information about the fruit's maturity level and their oil content to make accurate predictions on the expected performance of the crop so that the farmer can get these parameters from his plot in real time and can determine the best moment to harvest.

In the waste collection sector, the smart cities solution's specialized company, Wellness Telecom has the product family QUAMTRA being an intelligent Urban waste collection system. The system optimizes collection routes by constantly monitoring the content level of waste containers. The system includes hardware device for both measuring waste container fill level and collecting data, and a software platform for data management receiving real-time alerts on content level as well as temperature variation of the containers. The solution can effectively reduce collection costs and GHG emissions. This system has been successfully implemented in the city of Seville in collaboration with the municipal waste collection company (LIPASAM), covering a wide area with 268 containers. Currently, the company is exploring possibilities for adapting the system to other waste and biomass types.

The afore-mentioned company SOLTEL IT has also an Industry 4.0 solution consisting in monitoring the performance of an industrial plant down to the tiniest detail, taking full advantage of the Internet of Things and BigData technologies (INTRACE).

In addition, it has already existed in the industry 4.0 field, commercial products developed by the Andalusian company IDAB-IIoT. Based on a high-performance microcontroller the Idaab-IIoT platform has been designed to provide high-connectivity to industrial equipment. It collects both analogical and digital signals over input and output cards. The microcontroller can automatically measure, analyze and send the parameters information to the cloud server where the IT specialized SW is installed. The advanced software integrates predictive maintenance and asset management functionalities, so that the information can be provided to the client.

3.1.2.3 Algae

This value chain is still emerging in the region so no specific ICT tools for algae have been identified yet. Companies operating in the field usually use ICT tools developed by themselves so no much information is made publicly available.

4 Background related to DIHs in the ICT-BIOCHAIN regions

4.1 DIHs currently or previously implemented

In this section, DIHs initiatives existing in the Model Demonstrator regions will be commented. Consolidated initiatives, as those which have been included in the Digital Innovation Hubs catalogue [19], are described, together with emerging initiatives that have their foundations in Smart Specialization Strategies aspects.

4.1.1 South-East Ireland

4.1.1.1 Manufacturing Industry Digital Innovation Hub

Irish Manufacturing Research (IMR) is a research and technology organization focused on advanced manufacturing. IMR is a partner on the €8.5million H2020 project Manufacturing Industry Digital Innovation Hubs (MIDIH). With 21 partners from 12 EU countries, including, Competence Centres, Digital Innovation Hubs, CPS/IOT Technology Providers as well as Lighthouse Manufacturing Industries, the vision of the project is to place Europe at the forefront of the 4th Industrial Revolution, through creation of technological services (interactive demos, pilot lines, hackathons), business services (innovation processes, business acceleration, brokerage, access to finance), training and skills development, which will not only help SMEs and corporates to understand the new technologies, but also take full advantage of them, providing an operational framework that will stimulate trust, confidence and investment. Within the MIDIH project there are two digital innovation hubs, one formed by IMR and another based in Strathclyde, the remaining partners serve as competence centre partners, taking learnings from the two Digital Innovation Hubs in order to establish future DIHs.

4.1.1.2 Dingle Creativity and Innovation Hub

The Dingle Hub is located in the Dingle Peninsula in Co. Kerry in the South West of Ireland. The Hub is a community enterprise initiative supported by a range of significant regional partners including their, Dingle Business Chamber, Údarás na Gaeltachta, Kerry County Council and Net Feasa. The hub has 4 key focus areas including – Arts/animation, music, sustainability and low carbon technologies and Internet of Things (IoT). The dingle hub examines the role that IoT can play in supporting local business and the community in meeting their objectives. A unique testing platform for the Internet of Things (IoT) – how everyday devices connect and communicate with each other via the Internet – is also being developed at Dingle Digital Hub. The Hub will examine the role that IoT can play in

improving the sustainability of various enterprises including farming. The Hub is also home to participants of the Dingle Renewable Demonstration Village a €4 million project that positions Dingle as a test-bed village exploring how the smart electricity network of the future will operate. The initiative will see new and existing homes fitted with solar panels, electric vehicle charging points and battery storage to see how the grid copes with additional demands for power.

4.1.1.3 Smart Agri Hubs

Smart Agri Hubs is a recently announced €20m EU initiative which aims to build a pan-European network of Digital Innovation Hubs (DIHs) and Centres of Competence for the Agriculture Sector. In all the initiative involves 28 European Member States coordinated through nine regional clusters. In Ireland Waterford Institute of Technology, which has developed smart agri expertise through its Telecommunications Software & Systems Group (TSSG) research centre, will lead one of the regional clusters coordinating activities for the UK and Ireland. The clusters will act as a one-stop shop for farmers and the agri-food industry to access agri-tech research and projects. Farmers, advisors and ag-tech SMES can engage with research centres and research-active higher education institutions through the Smart Agri Hubs initiative. As part of the project, 80 new solutions will be introduced into the market. Some €6m has been set aside for open calls during the lifetime of the project. As the co-ordinator for the UK and Ireland regional cluster, TSSG will be the central point of contact for farmers, advisors, ag-tech and agri-food companies who want to avail of technology solutions from across Europe to address farming and business problems. The project is coordinated centrally by Wageningen University and additional Irish partners include Teagasc, Munster Ai Farm Services, Irish Cattle Breeding Federation Society Limited and Energy Monitoring Ireland Ltd. Andalusian region also participates in this initiative and, together with a Portuguese company, takes care of Iberian area.

4.1.1.4 Dublin Digital Hub Project

The Digital Hub project is an Irish government initiative, managed by the Digital Hub Development Agency, an Irish state agency aimed at creating an international centre of excellence for digital content and technology enterprises. It is located in Dublin's south-west inner city, and is home to 90 digital enterprises employing 980 people. The companies range from start-ups to well-established businesses that are significant employers and leaders in their fields. Since the project's inception almost 200 companies have progressed through the Hub including some now well-established names such as Daft.ie, Havok, Houghton Miflin (Riverdeep), Amazon, PopCap, Gala Games. The campus comprises a nine-acre site, of which over 50% has been developed. The remaining sites will be developed as part of the new strategy for the DHDA, working with Dublin City Council in particular.

4.1.2 Andalusia

4.1.2.1 DIH Andalusia Agrotech

In the framework of Smart Specialisation Strategy of the region (RIS3), Andalusia region through the Regional Government of Agriculture, Fisheries and Rural Development lead the Thematic Partnership "S3P Agri-food about Traceability and Big data". This partnership has an Andalusian node which connects regional partners in the agri-food Sector, Technological Sector and Competence Centres (Universities, Research Centres and Technological Centres) as well as citizenship.

Nowadays, this entity is composed by more than 100 partners which actively collaborate to encourage, motivate and facilitate the incorporation of digital technologies and data application in agri food sector value chains.

By taking advantage of this initiative, Andalusia is fostering the implementation of an Agrotech Digital Innovation Hub called "DIH Andalusia Agrotech". For this purpose, Andalusia has analysed the potential stakeholders though interviews and surveys as well as co-creation sessions to relevant actors in the field, including the public sector. This DIH Agrotech is being created to answer the needs of innovation and digitalization spotted in the agri-food sector so as to enhance the competitiveness of the region.

The DIH Agrotech is a model of open innovation which attracts and links actors, capitalizes talent and resources to activate and scale-up strategic opportunities for the long-term success of their companies.

Figure 5. DIH Andalusia Agrotech

Its vision is to be a reference in European digital innovation applied in the agri-food sector, by promoting digital culture and by creating and adapting business models to the digital era.

Its mission is to reach all the companies in the sector from a technical and economical perspective by adapting technologies for the agri-food sector. The Andalusia DIH Agrotech has three main features:

- *Open*: It is a collaborative environment to connect talent, companies, technologies and ideas in an agile and flexible scheme to inspire and attract agri-food reference companies, entrepreneurs, start-ups and excellence international leaders.

- *Innovative*: Its vision is to work looking ahead with a compromise of being innovation leaders, to anticipate sector needs in the regions and to transform business models.
- *Global*: Its holistic point of view is based on a deep knowledge about the sector to produce communication and action protocols based on information and knowledge acquisition from agent behaviour.

It is planned to launch this DIH during the last quarter of 2018, including its strategy and governance as well as its first services for early adopters. Its implementation will be done during 2019 and its consolidation will be made in three steps: capillarity, scale-up and leadership.

The DIH will be created in the frame of ICT-BIOCHAIN project and so, will be integrated with this hub, in order to make the most out of potential synergies, widening this way the potential impact on the regional competitiveness and growth.

4.1.2.2 Andalusian Bioeconomy Cluster

Thanks to the selection of Andalusia as a Model Demonstration Region in Sustainable Chemistry some recommendations were received through a Policy briefing. Some of them were directly related to the need of stakeholders engagement, to be achieved by the following actions:

- Performing a stakeholder analysis into biobased champion companies and invite them to match-making sessions.
- Organizing Andalusian bioeconomy Matchmaking Events.
- Creation of a coalition of willing assisted by the Horizon 2020 funded projects Superbio and Agriforvalor.

These recommendations set the path for the Andalusian Bioeconomy Cluster. A broad range identification of agents involving public sector, industry and knowledge agents has been done.

Nowadays, Andalusian Bioeconomy Cluster is in its seed phase with the objective of maximizing competitiveness and companies success by taking advantage of network opportunities. For this reason, collaboration and cooperation networks among companies of apparently diverging sectors need to be created in order to promote regional growth. More specifically, the objective of the Andalusian Bioeconomy Cluster will be aligned with the Andalusian Circular Bioeconomy Strategy: to promote competitiveness and development of bioeconomy sector in Andalusia by fostering cooperation processes through innovative projects and enhancing entrepreneurship in the sector. This way, the number of bioeconomy companies will rise and its visibility will be fuelled. Its implementation is considered therefore as key action of the Andalusian Bioeconomy Strategy.

This cluster aims to organize the bioeconomy sector including the participation of public-private agents like Andalusian Technological Corporation. Also, it will help facilitating the

access to knowledge and will improve bioeconomy sustainability aspects awareness. The Andalusian Bioeconomy Cluster addresses some key elements which are present in the region to achieve these goals:

- *Sector specialization*: Companies involved in bioeconomy value chains such as biomass producers, procurement and suppliers, knowledge centres and related actors.
- *Concentration*: Local biomass and rural characteristics of Andalusian bioeconomy will be considered during cluster implementation.
- *Agile structure*: It will be dynamic and influenced by regulatory, profitability and environmental aspects.
- *Public role*: It will be launched with assistance from public entities but will be led by private sector.

Two more clusters in seed phase have been identified in the region concerning forestry and water resources, which are initially promoted by the Strategic Plan of the Regional Agency for Environment and Water.

4.1.2.3 Linares 4.0, Knowledge City (DIH)

This DIH is listed in the EC catalogue. It is coordinated by the Linares (Jaen province, Spain) Chamber of Commerce and Industry and located in the Scientific-technologic campus of Linares (Jaen).

Main partners include the University of Jaen, Diputación Provincial de Jaén (Province Public Government), Ayuntamiento de Linares (Local Public Government), Innovative Business Group Automotive Sector of the Province of Jaen and the Regional Business School (Escuela de Organización Industrial, EOI).

Linares 4.0, Knowledge City (DIH) offers all the space and resources you need to successfully compete in the Knowledge Economy. At Linares Sci-Tech Campus you will find modern infrastructures, advanced services, financing programs and facilities to develop R&D projects. Besides, in Linares you find the main assets to increase company's competitiveness: a highly-qualified human capital and an open innovation system where both companies and students do collaborate to find innovative solutions to business problems. All these points are based on the location within a same space of: -A Scientific and Technological Campus that has advanced infrastructures for research and development in IT and new materials. -The Technology Centre of Metal-mechanical and Transport, that has a great and qualified number of engineers, as well as of diverse laboratories and a climatic chamber (unique in Andalusia) in which to carry out diverse tests (products and materials). -Sicnova Group, national leader in manufacturing and distributing 3D printers and scanners, with a significant representation in Europe and Latin America. -Various companies dedicated to software development, mobile app, gamification, network and telecommunications infrastructures, virtual reality, etc... -Public entities such as the City Council and the Chamber of Commerce of Linares, which provide support for the search for funding, search for new business opportunities, and

catalyze the system. -Coworking spaces and business incubation, supported by the mentoring and synergies generated by the entities mentioned above. All efforts are focused on improving the competitiveness and development of companies and entrepreneurs based on new technologies and industry 4.0 as a key factor for change.

Customers are around 26-50 annually and they include:

- Start-up companies
- SMEs (<250 employees)
- MidCaps (between €2-10 billion turnover)
- Large companies, multi-nationals

Regarding main activities linked to national or regional initiatives for digitising industry, the added value of this initiative is based on an ecosystem that centralizes, by locating within a same space, different types of entities (all technological) that, through the qualification of each, form a perfect model "all in one", which allow companies and society access the tools, knowledge and human resources needed to move forward, by taking innovation as the basis for growth. Having a university with engineers and laboratories for the development of new materials, a Technology Centre of Metal-mechanical and Transport, software design and connectivity companies, as well as a company specialized in 3D printing and 3D scanning, all together constitute a catalyst capable of giving Support-Through-Group-Work to any other company that does not have the necessary personnel or technology. This ecosystem, through digitization, allows any company or training center to cover or improve their needs and be more competitive, adapting to the new times, by developing new products or processes, as well as improving those that already exist. This support based on the collaboration and backing of qualified and technology entities, is basic to be the engine that generates support and acceleration for the change needed in the productive models.

4.1.2.4 OnGranada - Granada Plaza Tecnológica y Biotecnológica

This DIH is listed in the EC catalogue. Coordinated by Cluster Association “Granada Plaza Tecnológica y Biotecnológica” – Granada Tech and Biotech Square-, On Granada Tech City is located in Granada.

Main partners include Clúster Andalusia Smart Cities, Banco Sabadell, Mulhacen School, BStartup, Agencia IDEA (regional public organisation), Granada chamber of commerce, industry and navigation, University of Granada, Professional association of ICT engineers from Andalusia and Junta de Andalusia (regional government).

The mission of this DIH is the promotion of innovation, development of R&D projects, promotion of the transfer of knowledge, promotion of entrepreneurship, attracting investment, creating zones or developing the use of existing zones where companies are grouped, promotion of the creation of qualified employment and promotion of digitization.

On Granada Tech City aims to place the companies of Digital Economy sectors, Biotechnology and of sciences, and technologies applied to Health, in the position of leadership at national and international level, as well as to contribute to the digitization of the productive sectors of Andalusia. Main scope within Andalusia are the sectors ICT, BioICT, and applied Health Sciences and Technology.

Services provided are: (I) Observatory of industry 4.0 and Applied Health in sciences and technology (II) R & D projects. (III) Invigoration and promotion. (IV) Training and employment. (V) Entrepreneurship.

Most relevant action is the Observatory of Industry 4.0 and Applied Health in sciences and technology. This observatory has a double objective; on the one side, it has real and faithful information on the lines of R & D and innovation in the field of Industry 4.0 and sciences and technologies applied to Health currently in Andalusia. On the other one, carrying out a "Technological Watch" work detecting all the digital technologies and solutions that are being developed at a national and international level.

About R&D projects, the needs of associated companies in the field of R & D, including Industry 4.0, and the new developments or technological solutions detected above is reflected in the following lines of projects:

- Technical Feasibility Studies
- Industrial Research
- Experimental Development
- Innovation in organization
- Innovation in processes

Dissemination, communication and promotional actions are channeled into:

- Improving the development, attraction and retention of human capital.
- Stimulating innovation and entrepreneurship in the field of Industry 4.0, Bio TIC sector and Health Sciences and Technologies, including spin off, as a basis for the economic and social development of Andalusia.
- Promotion of R & D and knowledge transfer .
- Guiding companies towards the intensive use of new technologies.
- Development of pilot experiences, concept test and demonstration projects.
- Promotion of the incorporation of technological solutions in a way that improves the competitiveness of companies.
- Stimulating the innovation and technological specialization of companies.

Concerning training and employment, training programs are designed to meet the needs of companies. The actions envisaged in this area are:

- Identification of the needs of companies in the development of new products and services.
- Identification of substantial improvements in existing products and services in companies.

- Basic training for the creation of conceptual concepts about applied creativity and innovation.
- Advanced training through advanced seminars, thematic sessions and technical sessions.
- Training and methodologies for the introduction of new working methodologies in the field of applied creativity and innovation. Service of Entrepreneurship.

The DIH has also a financing related service. The aim of this service is to find the necessary financial instruments for the promotion of entrepreneurship and companies in the field, mainly SMEs, to carry out their R & D initiatives, including Industry 4.0, and thus improve their competitiveness, growth and internationalization.

Customers are more than 50 annually and they include Start-up companies and SMEs. Regarding main activities linked to national or regional initiatives for digitising industry, the added value of this initiative focuses on:

- Sensors and embedded systems. Components, subassemblies and electrical and electronic systems including the development of software and firmware necessary to guarantee their functionality.
- Business and intelligence solutions. Innovative applications of management, which process and use information obtained from activities of the production & supply chain, commercial, financial and human resources ones.

4.1.2.5 National Pole of Digital Content, POLO

This DIH is listed in the EC catalogue. It is coordinated by local public organization in charge of entrepreneurial aspects (Empresa Municipal de Iniciativas y Actividades Empresariales de Málaga S.A) and it is located in Málaga.

Main partners include local economic development agency (PROMálaga), Red.es (national public body), Business school (Escuela Organización Industrial, EOI), the University of Málaga, Spanish association for videogames and leisure software producers, Genera Games, PITA- Andalusia technological park, Videogames developers association from Malaga and Andalusia Media Alliance, AMA.

POLO is an ecosystem of promotion of the sector of digital content, led and supported by PROMálaga, that manages the facilities and laboratories, located in the 'Tabacalera of Malaga', where ProMálaga supports companies and startups of the sector with digital contents, oriented to boost the talent, through training and education, entrepreneurship, growth, scaling up and internationalization of the Digital Content industry. The mission of POLO is to promote the hyper-sector of digital content in Spanish society through innovative and the articulation of initiatives in a global environment of collaboration with public and private partners. Its scope is to be a national and international reference, in the hyper-sector of digital contents for the improvement of employability, the quality of living for the society and the competitiveness of companies.

POLO provides Innovation, Business Development and digital training services as one-stop-shop, helping startups and companies to become more competitive, improving their products and services through digitalization. It has laboratories of Virtual Reality and Augmented, Motion Capture, Video Recording, Photography, Sound Recording, Graphic Design and 3D Printing to facilitate access to cutting-edge technologies to the company, reducing entry barriers for the adoption of these Innovations.

Regarding main activities linked to national or regional initiatives for digitising industry, POLO has been conceived as an itinerary in the sector of the digital contents composed by innovation activities, business development and digital training. It has facilities that act as one-stop-shop for access to digital content technologies, reducing adoption time and entry barriers to startups and SMEs.

4.2 Barriers overcome

Organisations involved in the development and implementation of the DIHs presented herein faced several barriers during the DIHs set-up stage. These barriers were overcome in due time as these initiatives are today an example of successful ideas and projects.

Identifying the barriers that have been overcome will allow ICT-BIOCHAIN to capitalise on regional partners knowledge concerning local and regional aspects and dimensions to be considered.

4.2.1 South-East Ireland

Irish feedback indicates that certain barriers need to be overcome in the establishment of digital innovation hubs including defining what is achievable and within the scope of the hub. Digital Innovation Hubs often have an overly broad remit and a large focus on technology and applications areas, making it challenging to achieve practical outputs which benefit companies. Sometimes a more focused approach will achieve better results. Other support services offered by Digital Innovation Hubs include business supports and access to financial partners. It is important that these aspects receive adequate attention and resources. Sometimes referral to other technology centres, for example research centres, is appropriate particularly where TRL levels are low. A key barrier is demonstrating industry relevance and benefits to the different industries (and other) partners. Another challenge can be the geographic fragmentation of companies associated with the hub and the technology providers which can make technology access or demonstration more difficult to achieve.

4.2.2 Andalusia

The following barriers have been identified for both Andalusian Agrotech DIH and Bioeconomy Cluster. These are analysed from the point of view of primary producers, agri-food sector, IT companies and knowledge providers. Most of the implementation barriers have been related to agrotech adoption.

Sector	Barrier
Agri-food Sector	▪ Limited access to IT infrastructures ▪ Low qualification of primary sector employees ▪ Low availability of guidelines and best practices on ICT use regarding agriculture ▪ Cost-benefit of the solutions offered by the DIH are sometimes not clear for the users ▪ Companies are scattered geographically in the region ▪ Low investment on IT technologies, not availability of integrated solutions ▪ High competitiveness of the sector makes agroindustry to invest their time in other issues such as quality certifications, machinery etc.
ICT Companies	▪ Usually ICT companies are focused in other sectors such as banking or retail and most of their solutions are not developed for agri-food sector ▪ Scarcity of professionals with a combined ICT-agriculture education
ICT Knowledge	▪ Lack of specific funding tools for this type of research ▪ Lack of connections between agriculture and knowledge sectors

During the implementation of the DIH some of these barriers have been faced by using a multilevel approach:

- Previous experience gained in the thematic partnership of traceability and big data served as starting point for DIH building. The procedure for joining to this partnership was done by means of sending an email including a letter confirming their interest to participate in the node. This previous step allowed Andalusia to identify all the potential stakeholders and to connect them.
- External advice about different strategies and possibilities have been received to conceive the DIH idea.
- It was essential to identify a clear value proposition of the introduction of digital technologies in the agri-food sector adapted to different agents.
- Communication and dissemination involving different key stakeholders with influence in their sectors. For example, involvement of primary production associations has been proved as a smart strategy to engage farmers and to access with capillarity to all the territory.

4.3 Lessons learned

From the overcome barriers and the practical experience gained through the last years, a group of lessons learned can be drafted. This information will become very valuable when designing and implementing the DIHs in the model demonstrator regions.

4.3.1 South-East Ireland

Feedback from Irish Digital Innovation hubs indicated that industry engagement early in the project will provide the most practical outputs and improve participation in CSA events. Getting an understanding of the needs of industries participating is essential. Digital Innovation Hubs should have an industry focus, so technologies should be focused on higher Technology Readiness Levels. Rather than scoping the most elaborative and innovative technologies that could be applied within value chains, consideration needs to be given to fact that sometimes industry needs require more practical and sometimes more basic solutions. In building capacity and gaining interest from stakeholders, demonstration can be an effective tool. Demonstration can be provided via tours, on-site demonstration, or using virtual demonstrations of technology in use in a relevant environment. Irish feedback suggests that the biggest impacts of a demonstration day will be seen when industry (rather than academia or technology providers) discuss the technologies that they have integrated, and inform stakeholders about the way in which this technology has improved efficiency or added value to their process. This approach is likely to gain greater interest from other industries/primary producers in the space, as they see that the technology has a real-world application. Sometimes it may be necessary to explore the opportunity of a company opening up or widening out the use of a high potential technology to benefit other participants.

4.3.2 Andalusia

Andalusia has identified several items which are helping to foster the DIH implementation. Most of them are related with the importance of communication and dissemination plans as well as a well-formed DIH service definition. In this case, it was clear that the participation in European Initiatives was vital to learn different DIH experiences and to gain know-how, thanks to the leadership of the thematic partnership in 'Traceability and Big Data'. Participation and organization of local and interregional events, workshops and conferences helped Andalusia to establish a wide collaboration network for experience exchange.

In the case of Andalusian Bioeconomy Cluster, co-creation sessions have been performed with a reduce group of collaborators covering the different profiles involved in bioeconomy. During these sessions all the participants had the opportunity to express their concerns and opinions about how the cluster should be.

In addition, in the framework of the Andalusian Bioeconomy Strategy, the idea of constituting a bioeconomy cluster was discussed with almost 50 experts which expressed their contributions:

- Andalusian Bioeconomy Cluster should be inclusive, considering international relations.
- Andalusian Bioeconomy Cluster should include the participation of other industries such as chemical industry, agriculture or automation to consider the markets for the bioproducts or bioenergy.

- Competences of Andalusian Bioeconomy Cluster should be clearly defined, and a dynamic structure needs to be set-up.
- It is necessary to avoid duplicated entities and to join all the efforts in one strong initiative.
- Public administrations have the role to start and promote this action, but it is the industry the one that should lead the consolidation and growth of the cluster.

5 Barriers identification for ICT-BIOCHAIN DIHs implementation

Main barriers to be faced when developing ICT-BIOCHAIN DIHs are identified next. A preliminary brainstorming session has been conducted in order to identify some mitigations actions. These actions and strategy will be further defined and implemented during the DIH structure definition and stakeholder mobilisation phase.

5.1 South-East Ireland

Barrier identification	Definition	Some proposed actions for mitigation
Accessing information on existing technologies/best practices	Companies may be reluctant to provide information on technologies used to improve their supply chains	The project builds on already established links with industry including Irish Bioeconomy Foundation, AgriForValor and IMAR and will link to relevant companies to help establish best practice
Lack of motivation from biomass suppliers to improve their local supply chains	Lack of facilities and knowledge regarding processing of agricultural residues for bioeconomy applications	The fact that the focus area of the project is around the national bioeconomy campus at Lisheen, which is already developing piloting and flagship actions will help to improve knowledge and visualisation of opportunities for new value chains involving primary producers.
Lack of regional focus	The information collated by the hub is too general	A focus of the project is to access regionally available information on biomass and bioresource availability to complement scoping on technology availability
Low stakeholder involvement	Stakeholder participation in project activities is low	The project builds on already established networks including bioeconomy, technology and

		primary producers to bring knowledge on bioeconomy and its intersection with ICT to a broader audience, including through a number of work package 4 events.
Meeting the needs of industry/stakeholders	Unable to define relevant technologies due to lack of awareness on needs of industries	The hub helps to define available feedstocks, and key areas of technology applications across a broad range of feedstocks to ensure the best possible opportunities for relevant outputs

5.2 Andalusia

Barrier identification	Definition	Some proposed actions for mitigation
Lack of motivation from biomass suppliers to improve their local supply chains	Lack of information about possible applications and biomass markets can cause lack of interest in biomass suppliers, in order to improve their current practices	Include biomass clients (bioindustries) in the DIH. Clear example and business cases will be shared during project execution
Low stakeholder involvement	A lot of SMEs and small producers are family-owned business, with pyramidal decision-making mechanisms that make difficult the development of new cooperation opportunities for technology transfer	Active communication, events, B2B meetings, etc. LoI signatories will be included from early steps of the project in the communication activities
Knowledge gap within companies	Agriculture is a very traditional sector which innovation promotion and implementation are complicated.	Potential gains due to innovations should be clearly explained Tailor made communications will be done
Low coordination between value chain stakeholders	There are several local groups of producers but there is not a coordinated effort for value chain development and new	DIH will have a strong local component with the main objective to improve and increase the communication between

	business opportunities development	regional stakeholders, from both private and public sector
Legal form for the DIH establishment	There are several strategies for the legal establishment of the DIH. Hence, final strategy must be carefully selected as it could limit the dynamics of the DIH	Deep analysis about the different options and advice from specialised consultants will be performed
Definition of DIH value proposition	A wrong definition of the value proposition can affect the future development of the DIH. A clear offer to the partners to meet their needs should be done, in order to ensure long term viability. Service level and funding scheme require a fine tune description during strategic DIH development	Business models following the concept of CANVAS (considering biomass resource and market, supply chain relationships, revenue streams, key activities, key partnerships, cost structure) will be offered to innovation partnership members. To allow the progress of these innovations to the next level, the regional facilitators along with MDR partners will co-host an 'Investment Day'
Lack of specific financial instruments	There are not existing tools for DIH establishment in the regions. These structures should be built on the basis of partners contributions and a mix of existing tools	During DIHs implementation in the MDRs a detailed plan will be done to analyse different options for initial funding
Low data availability and specific applications to bioeconomy	Acquired data for agricultural sector need to be adapted to address main inputs needed for its implementation in bioeconomy. Most of the applications and data are focused in primary production for human consumption.	State of the art about available technologies and user requirements survey will be performed

6 Conclusions

A review of the value chains considered in the frame of the project has been conducted and some preliminary stakeholders have been identified. Due to the fragmentation of the different biomass producers, building on the existing logistics systems, the bundling of

similar types of agri-food waste streams in one location could create the boundary conditions for a viable business case based on fibers for composites, rheology modifiers, pectin for gels and sugars for food or bioplastic applications or different plant bioactive compounds for biofertilizers or nutraceuticals production, as well as any other relevant biobased products that could emerge from the biomass processing.

Regarding ICT, IoT and Industry 4.0 both regions have several solutions available in the market that aim to make farmers work easier. These products are usually focused on retrieving data and handling them in order to make the most out of available information. This goes from traceability and information availability for the consumer/biomass buyer to integration of information with weather forecast and plagues information in order to reach a cost and resource efficient planification and management of crops and farms. Nevertheless, there are no relevant or outstanding solution related to biomass logistics, being this a clear gap towards the sector full digitalization.

Past experiences with Digital Innovation Hubs (DIHs) in each region have been identified and described and overcome barriers have been analyzed. In both cases, regions pointed out as main barrier demonstrating industry relevance and benefits to the different industries (and other) partners. Another challenge identified is the geographic fragmentation of companies associated with the hub and the technology providers which can make technology access or demonstration more difficult to achieve. Main lessons learned from these experiences are: (1) relevance of understanding of the needs of industries participating; (2) big impact of a demonstration day when industry (rather than academia or technology providers) discuss the technologies that they have integrated, and inform stakeholders about the way in which this technology has improved efficiency or added value to their process; and (3) importance of communication and dissemination plans as well as a well-formed DIH service definition.

Finally, regarding the barriers identified for the implementation of the ICT-BIOCHAIN DIH, most of them are common for both regions. It is possible to group them around stakeholder involvement (e.g. lack of motivation from biomass suppliers to improve their local supply chains, ow stakeholder involvement and meeting the needs of industry/stakeholders), information availability (accessing information on existing technologies/best practices, knowledge gap within companies and low data availability and specific applications to bioeconomy) and DIH regional definition (lack of regional focus, low coordination between value chain stakeholders, legal form for the DIH establishment, definition of DIH value proposition and lack of specific financial instruments). A preliminary identification of means to overcome these barriers is presented in this deliverable, being further plans developed in the frame of WP2.

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