Ref. Ares(2019)7356869 - 29/11/2019

Deliverable 1.3. ICT, IoT, and Industry 4.0 technology opportunities for improvement of biomass utilisation

Acronym: ICT-BIOCHAIN
Project title: ICT-BIOCHAIN - ICT Tools in Efficient Biomass Supply Chains for Sustainable Chemical Production
Contract Nº: 792221
Start date: 1.6.2018
Duration: 24 months

Deliverable number	D1.3
Deliverable title	ICT, IoT, and Industry 4.0 technology opportunities for improvement of biomass utilization
Submission due date	M18 – 30.11.2019
Actual submission date	29/11/2019
Work Package	WP1
WP Lead Beneficiary	VTT
Dissemination Level	Public
Version	03
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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

DOCUMENT CONTROL PAGE

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Version history

#	Reviewer	Comments
00	Authors	Document structure, first draft
01	Authors	Advanced draft with content
02	Authors	Complete draft frozen for consortium review
03	All	Final version

1. Executive Summary

This report summarizes a study conducted within ICT-BIOCHAIN project on technological opportunities for improvements in biomass utilization. It includes a collection of identified needs, which are currently not met within supply chains of organic material, as well as barriers, which can hinder the adoption of ICT, IoT, and Industry 4.0 tools in biomass supply chains. This information was collected using two different methods:

a) Analysis of the current state of the art in ICT, IoT, and Industry 4.0 solutions for biomass supply chains mapped earlier within the project [1].
b) Obtaining data from participants of Digital Innovation Hubs (DIHs) Launch Events with questionnaires and workshops exercises.

This collection is used to identify improvement possibilities within biomass supply chains using innovative technologies. Therefore, it will provide an input for planning of the actions to be undertaken by the DIHs formed by the ICT-BIOCHAIN project in the model demonstrator regions (MDRs) of Andalusia, Spain and South-East Ireland.

Content

2. Acronyms and abbreviations

ALS	Airborne Laser Scanning
CCTV	Closed-Circuit Television
DIH(s)	Digital Innovation Hub(s)
ERP	Enterprise Resource Planning
GIS	Geographical Information System
GPS	Global Positioning System
ICT	Information and Communications Technology
IoT	Internet of Things
MDR(s)	Model Demonstrator Region(s)
ML	Machine Learning
NIR	Near-Infrared light range
NIRS	Near-Infrared Spectroscopy
QR code	Quick Response code
R&D	Research and Development
RFID	Radio Frequency Identification
SAP	Systems, Applications and Products
TRL	Technology Readiness Level

3. Introduction

Development of bioeconomy requires achievement of critical mass at both regional and global levels, and thus significant improvements in biomass utilisation are needed. These improvements can be obtained with various means, e.g., legislative (applicable laws and tax practices), organisational support from authorities, and technological. In this study, the focus is on the ICT, IoT, and Industry 4.0 opportunities to improve the biomass supply chains.

Within tasks T1.1 and T1.2 of the project, the regional and pan-European state of the art in ICT, IoT, and Industry 4.0 solutions for biomass supply chains was mapped and presented in report D1.1 "***Assessment of the current ICT, IoT, and Industry 4.0 solutions in European biomass utilization***" [1]. Based on research of finished projects, their reports, and other studies, as well as questionnaires and phone interviews with stakeholders, nearly 80 examples of relevant technologies, products, and services were described, and both their current and potential applications to biomass supply chains was assessed. In addition to the above-mentioned overview of the existing situation, the ICT, IoT, and Industry 4.0 needs, which are currently not met, were also surveyed – including identification of possible improved practices that could be enabled with use of ICT, IoT, and Industry 4.0 solutions. The regional stakeholders were given a chance to express their interests as well as to share their concerns and issues regarding the adoption of new technologies. They have identified several barriers that hinder the penetration of the ICT, IoT, and Industry 4.0 solutions into biomass supply chains, and the required enabling actions were discussed. The outcomes of these studies are described and explained in this report.

This report is organized as follows. Section 4 describes the methodology and data sources utilized in collecting information. Section 5 shows improvement possibilities within the whole biomass supply chain and applicable technological solutions. Section 6 focuses on barriers that hinder the adoption of ICT, IoT, and Industry 4.0 tools in biomass supply chains, and related main needs of the stakeholders, for which the two developed DIHs can provide support. Finally, Section 7 summarizes the work and draws some conclusions, while Section 8 provides a list of the most important references.

4. Methodology

To capture needs and barriers as well as to give an overview of identified possibilities for improved practices, two different approaches were used:

a) Analysis of the results and findings of previous tasks within the project
b) Fetching data from questionnaires and workshops (participants of DIHs Launch Events)

4.1. Analysis of regional and pan-European state of the art in the ICT, IoT, and Industry 4.0 solutions in biomass supply chains

The mapping of the ICT, IoT, and Industry 4.0 technologies and solutions started in previous tasks of the project with creating a common database format. This approach ensured the descriptions are uniform regardless of their origins - the same type of data was collected for applications within MDR regions of Andalusia and South-East Ireland, and Europe-wide. The format included specific inputs, which can help the user to filter data by various criteria, such as TRL level, year of deployment, cost estimates, etc. Information was provided on the current and possible future application of the technology within specific biomass supply chains. Technical aspects and the benefits to the supply chain including the overall environmental impact were also included. Contact information was provided in order to enable direct collaborations between the primary producers or bio-based industry and the technology providers.

ICT, IoT, and Industry 4.0 opportunities might arise from introduction of new solutions to the local stakeholders or from possible adaptation of existing technologies to applications in different type of biomass supply chains.

4.2. Fetching data from questionnaires/workshops within the MDRs

Within the ICT-BIOCHAIN project, two high potential model demonstrator regions are serving as test bed locations for the development of DIHs for the bio-based economy. These two newly established DIHs in Andalusia and South-East Ireland are represented by the project partners CAGPDS (former: CAPDER) and IBF, respectively. CTA (Spain) and ITT (Ireland) act as regional facilitators for these regions. In the implementation of the DIHs several steps are performed, starting with the establishment of the DIH network database and selection of the Hub Manager and Regional Steering Committee. This was followed by carrying out a DIH Launching Event in each region.

- The **Digital Innovation Hub Launching Event of Ireland** took place in Tipperary (Ireland) on July 12th, 2019 with approximately 60 participants.
- The **Launching and Knowledge Transfer Event in Andalusia** took place in Seville (Spain) on July 4th, 2019, also with approximately 60 participants.

Looking at the sectors represented by participants of the launch events in below figure, we see that R&D / technology providers were a dominant group, closely followed by the biomass producers and users. The third group were consulting institutions.

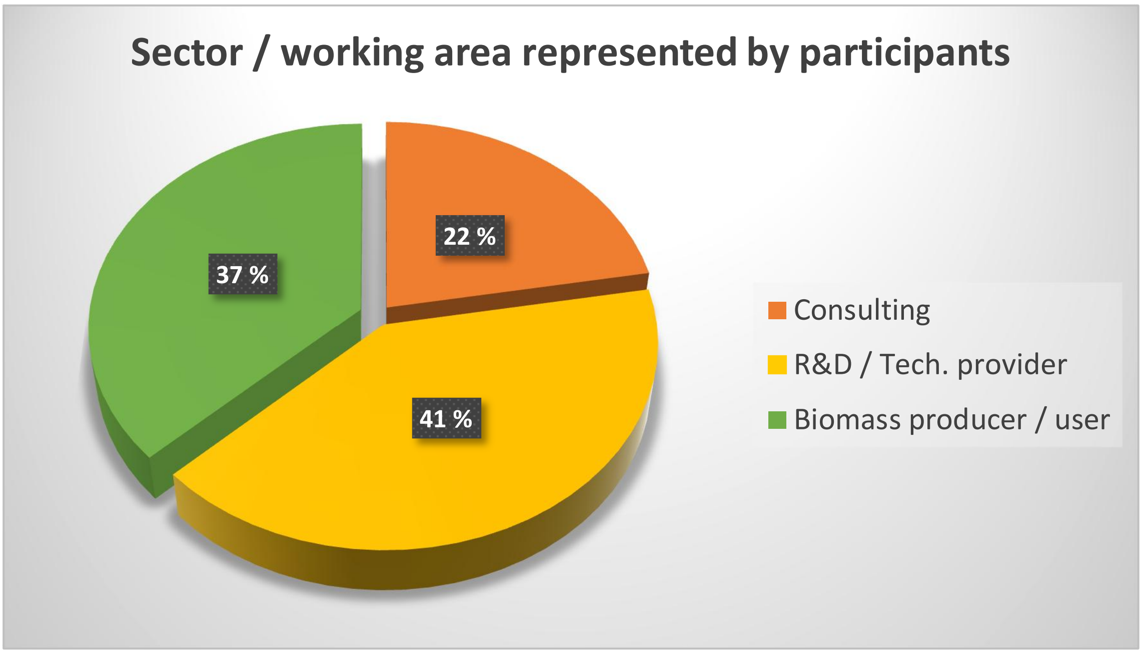

Figure 1: Sector affiliation of participants in DIH launching events

Most of the responders (41%) deal with biomass from agriculture (olive and horticulture waste, grass, livestock by-products). Significantly less (18%) work with forestry-generated biomass such as timber or pellets, 9% handles industrial biomass (e.g., waste), while 12% can deal with multiple types. Around 20% of participants do not currently work with biomass.

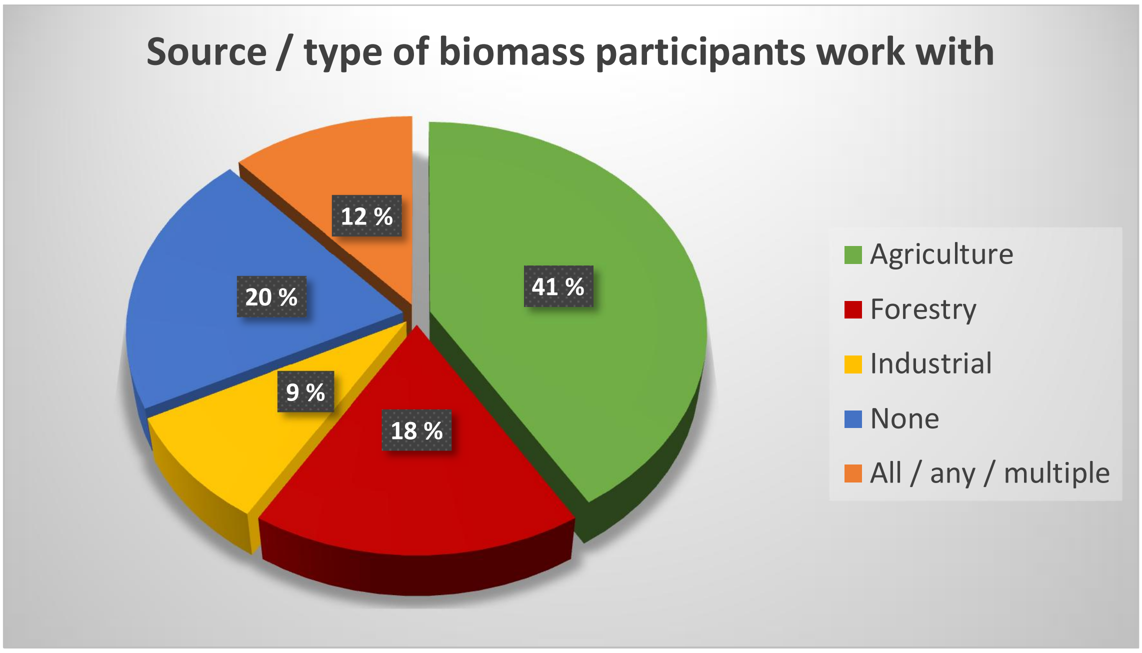

Figure 2: Source / type of biomass that participants of DIH launch events deal with

The participants of both DIHs Launching Events were asked to fill out questionnaires, to identify needs and barriers directly from the stakeholders. For that purpose, two forms were created: one for parties not implementing ICT / IoT technologies yet and one for parties already implementing ICT / IoT technologies (see Appendix 1).

Additionally, during the DIH Launch Event in Ireland, a workshop has been organised. The participants could choose which of the two main type/source of biomass (agriculture or forestry) they are interested in and then join the corresponding group. The main aim was to get their opinions on what ICT technologies can do for the sector of their interest. At the same time, the discussions provided insight on what issues the implementation of new technologies and solutions may involve, and which barriers are keeping the participants from implementing them. Members of the project team moderated the workshops to ensure that the participants are on the right track and that any questions they have about their task are answered immediately to avoid confusion. The group work was arranged into three sections with guiding questions:

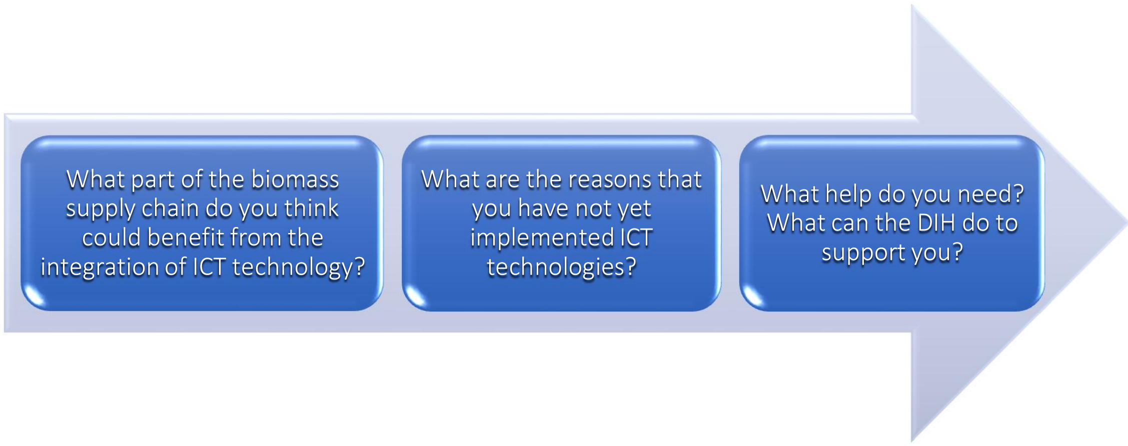

Figure 3: Questions guiding the course of the Irish workshop

Finally, during the Andalusian DIH Launch Event a workshop has been organised as well. Based on the experienced gained during the Irish event, the form and content were modified in order to provide a deeper insight. The discussions consisted of two parts with following objectives:

- to detect the needs of biomass-related companies and the ICT, IoT and Industry 4.0 offer from the technology providers, as well as barriers in cooperation and technology adoption;
- to identify what is expected from the DIH.

Within the first part, participants were divided in two groups: biomass-related companies and technology providers. Supported by the moderators (CTA staff), participants were asked to write their answers on post-it stickers. Then, the moderators presented the opinions gathered at each table.

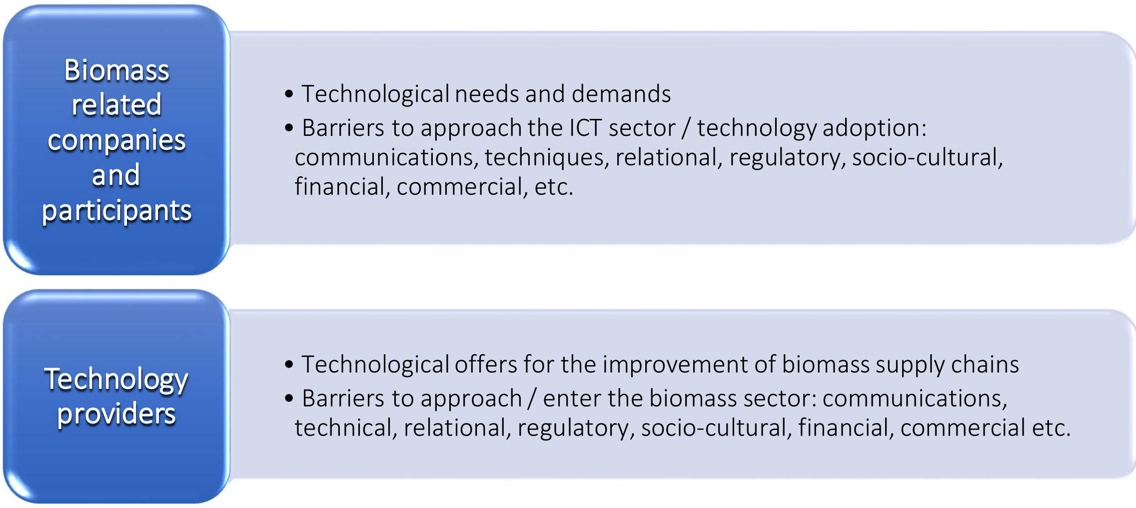

Figure 4: Structure of the first part of the Andalusian workshop

For the second part of the Andalusian workshop, participants formed mixed groups to discuss and about and formulate their expectations towards the DIH. Again, moderators supported the work, and the post-it cards were used to capture the ideas.

5. Technology opportunities in biomass supply chain

5.1. Opportunities within the supply chain

During the workshop at the DIH launching event in Ireland, participants were asked to indicate which part of the biomass supply chain could benefit from the integration of ICT, IoT, and Industry 4.0 technologies. Solutions or features were suggested for the individual stages in supply chain, i.e., **growing/harvesting**, **storage/pre-processing**, **transport** and **processing**, as shown below.

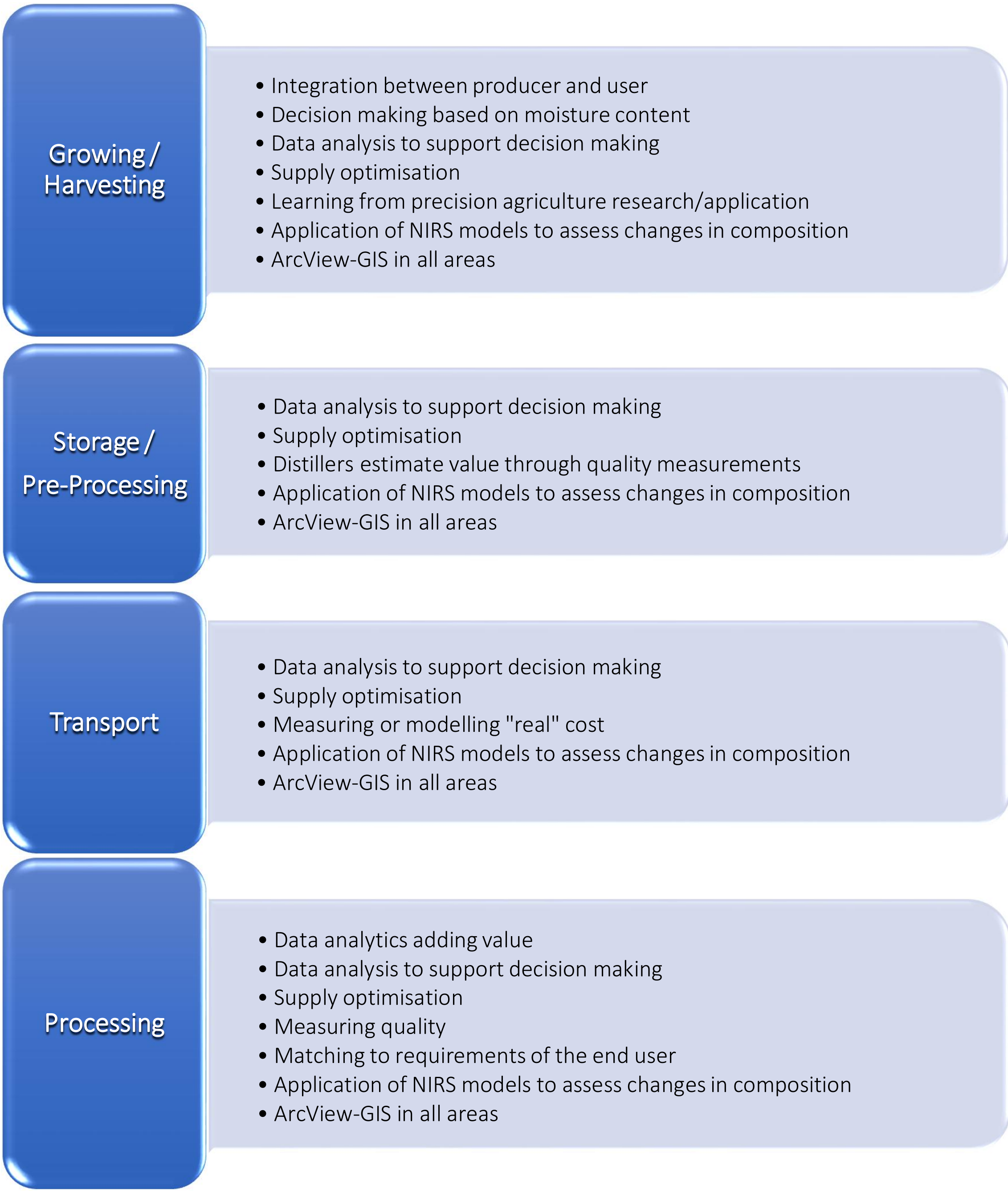

Figure 5: Integration of technologies in process steps of biomass supply chain

As can be seen, responders considered data analysis that supports the decision making and optimisation suitable and important throughout the supply chain. In addition, the location and geographical distribution (GIS) of biomass is useful for tracking and planning. Furthermore, monitoring and rapid assessment of the biomass condition (moisture, changes in composition) are considered beneficial at each stage of a chain.

Furthermore, by answering the distributed questionnaire the stakeholders could make additions beyond the predetermined process steps, which aspects of the organic material supply chain could benefit from the integration of ICT / IoT technologies. The suggested use cases included, for example, power plant logistics or greenhouse management and planning, "*sensorization"* and monitoring for recovery processes as well as physicochemical characterization for an optimization of the combustion process of a boiler.

5.2. Technologies of interest

Based on the analysis of technology mapping and insights of participants of both DIH Launch Events, following technologies, products, and services have been identified to provide opportunities for improvement of biomass utilisation.

Technology, solution or service	Brief description	Opportunity for improvement of biomass utilisation
Scottish Bioresource Mapping Tool	The tool provides knowledge of amount, type, and geographical spread of bioresources arising each year in the region.	Knowledge of available biomass with its type and geographic breakdown helps stakeholders in planning of new supply chains or biorefinery investments, leading to improved utilisation of biomass.
ERP, SAP	Enterprise resource planning (ERP) is the integrated management of main business processes, often in real-time and mediated by software — typically a suite of integrated applications — that an organization can use to collect, store, manage, and interpret data from many business activities. ERP provides an integrated and continuously updated view of core business processes using common databases shared across various departments (manufacturing, purchasing, sales, accounting, etc.). ERP systems track business resources — cash, raw materials, production capacity — and the status of business commitments: orders, purchase orders, and payroll. ERP facilitates information flow between all business functions and manages connections to outside stakeholders [2]. SAP ERP is an enterprise resource planning software developed by the German company SAP SE. SAP is an acronym for *Systems, Applications and Products* [3].	Internal control and management software useful for standardized overview and handling all aspects of a supply chain.

NIR(S)	Near Infrared Spectroscopy (NIRS) provides a rapid means to analyse a wide variety of feedstocks. Unique models allow the lignocellulosic composition of biomass samples to be predicted from their near infrared (NIR) spectra. Analytes determined include: Sugars (Monosaccharides), Lignin and Extractives and Thermal Properties	Faster (a day vs. weeks) and cheaper involves less laboratory work than the wet-chemical analysis), allows a far greater number of samples to be analysed. If used in industrial settings (e.g., within biorefinery or bioenergy facilities) can help select the best feedstocks and/or process conditions, so maximising process efficiencies.
GPS	Satellite positioning systems, such as the US operated GPS, European Galileo and Russian GLONASS are used to locate and track items.	It also allows geotagging, i.e., marking the location at which a certain item (e.g., biomass lot) was harvested or packaged. Monitoring the origin and track of a biomass supply may be used for proving the biomass provenience, and thus limit the illegal harvesting.
Lidar	The LiDAR (Laser Imaging Detection and Ranging) technology enables the automated acquisition of 3-dimensional (3D) data at a high rate. Weather and visibility hardly affect measurements, making these systems ideal for any surveying, inspection or mapping.	Inventory of biomass stocks through 3D mapping and analysis.
ALS	Airborne Laser Scanning (ALS) systems are LiDAR systems, which can be mounted on aerial vehicles such as airplanes, helicopters, and drones. ALS can be combined with e.g. GPS for precision mapping. Using different laser wavelengths and data processing algorithms enables to monitor different features. For instance, terrain conditions, seed and fertilizer dispersions, plant counting and species classification, crop mapping (growth rate, needs for maintenance, disease detection).	Can be used to optimize use of fertilizers or harvesting in precision agriculture and/or forestry, and thus can lead to increased biomass production, availability mapping and utilisation.
GIS, ArcGIS/ArcView	A Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyse spatial information, edit data in maps, and present the results of all these operations [4]. ArcGIS/ArcView is a GIS software developed by ESRI company [5].	Provides information on where the biomass is and how much of it. The geo-mapping can be applied at different stages in a biomass supply chain, from points of its origin (arising), through storage, logistics, and final destinations.
Machine Learning	Machine learning (ML) is the scientific study of algorithms and statistical models that computer systems use to perform a specific task relying on patterns and inference instead of explicit instructions. ML algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without explicitly programmed routines [6].	Predictions related to production, yield or biomass availability. Estimation of future market development.

ERPagro, Hispatec Analytics	ERPagro is a software toolset for the integral management of agricultural company's processes, from seed to dispatch to the end customer [7]. It consists of multiple modules aimed at different production aspects: - Pre-harvest solutions (from productive management of crops, seedbeds, supplies, to agronomic management of farms) - Post-harvest technology (control of all the of production and manufacturing processes, auctions, partners, suppliers, accounting and human resources) - Business management (advanced analytics tools, scorecards and custom reports). Hispatec Analytics is a service dedicated to big data analytics for agri-food sector [8], including: - Organisation and integration data from internal and external sources - Data models and technologies for predictive analytics - Tools for descriptive and diagnostic analytics.	Potential improvements through better decisions based on data and intelligence. Traceability.
Quanturi monitoring system	A wireless temperature monitoring system for composting or for storage of biomass (grain, woodchip, peat) or other materials (e.g., waste). It includes: - Temperature sensing - Wireless data transfer - Cloud data storage and processing - Reports and real-time alarms via SMS.	Maximizes the quality, the value and thus the efficient usage of biomass. Reduces biomass waste. Prevents spontaneous fires. Reduces work risks related to toxic fumes.
Agri MarketPlace	B2B marketplace between farmers and end users (industry/retail), offering such services as: - Digital Trading Platform - Sales Contracts Agreements - Logistics & Transportation - Quality Insurance of Products	Transparency - Direct transactions between farmers and industry or retail Fairtrade - Redistribution of value in food supply chain User Friendly - Reduce costs to buyers without losing reliability
RFID	Radio-frequency identification (RFID) uses electromagnetic fields to identify and track objects with attached tags, which contain electronically stored information. A tag can be combined with simple sensors (temperature) for condition monitoring. The tag need not be within the line of sight of the reader, so it can be embedded in the tracked object. Passive tags can wirelessly be read from up to 12m, while active battery-powered tags may operate even 100m from the reader.	Identification and tracking or access restrictions. Can be used to: - assure the provenience - reducing the biomass degradation - retain maximal value of biomass.
QR code	The QR code is one of the most-used types of two-dimensional optical code. It is a standard with commercially available code generators and readers. QR codes are already used in commercial tracking applications. QR code reading applications are also freely available for smartphones (camera works as a scanner).	Fast information sharing. Product or service identification. Traceability. Can also serve the same purposes as RFID, but is a significantly cheaper (e.g., free reader apps for mobile phones).

CCTV	Closed-circuit television, also known as video surveillance, uses video cameras to record and/or transmit a signal to a specific place (safety monitoring room, server, etc.). Traditional CCTV applications include security cameras in stores, banks, and restricted access areas. However, surveillance of the public using CCTV is nowadays common around the world, providing means for crime prevention/solving, traffic monitoring and increasing safety in public transportation. In industrial plants, CCTV equipment may be used to observe parts of a process from a central control room, for example, when the environment is not suitable for humans [9].	Remote monitoring of biomass growth rate, treatment process, or intrusion detection.

Many of those technologies offer significant benefits to the biomass utilisation improvements. For instance, knowledge of where, when and how much biomass is generated/available can lead to improvements in utilisation either via increased throughput of existing streams or by creating new supply chains. Information about the type and quality of an available biomass determines its possible use, and thus assessing the chemical composition is of utmost importance. Even simple estimation of a biomass moisture level may lead to significant improvements in optimisation of logistics and efficiency of the entire supply chain.

Generally, the main advantages of ICT, IoT, and Industry 4.0 solutions can be grouped in:

- Information management (agility, control, approach to end users)
- Decision-making support
- Process optimization, productivity and efficiency
- Cost reduction / increased profits
- Quality monitoring/assurance/evaluation of biomass in all its stage
- Safety assurance, fire prevention, elimination of work risks
- Reports for homologation
- Training solutions for personnel involved in operating activities

Furthermore, DIH launch events participants would like to know more about IoT and Industry 4.0 in general. Related terms such as remote sensing and biomass control were coined in the discussions without specifying any particular commercial solutions. This clearly indicates that such technologies and tools are of interest to stakeholders. Also, *big data*, *data analytics*, and *machine learning* were brought up by participants, who see a potential for improvements arising from collecting wide variety of information and ICT tools assisting in (or automating) its analysis.

6. Identification of barriers and needs

Once the opportunities within biomass supply chains are identified and the technologies of interest are mapped, two questions arise:

- Why these technologies are not yet implemented within certain organisations?
- What obstacles are faced during the process of adoption of new ICT, IoT, and Industry 4.0 solutions?

Answers to these questions are crucial in order to improve technology penetration into biomass supply chains. Therefore, participants of the DIH launch events were asked to list the obstacles as well as related needs for DIH assistance and support in overcoming them.

6.1. Barriers to adoption of new technologies

6.1.1. Identified at the early stage of the project ICT-BIOCHAIN

From the beginning of the project, the consortium attempted to assess the possible issues with implementing novel technological solutions into biomass supply chains, based on their experience in the bioeconomy field. At the same time, project partners put effort to devise counteractions and means to overcome these barriers.

- Biomass supplier (private sector) reluctance to ICT, IoT, and Industry 4.0 tools adoption

Agriculture is a very traditional sector where introduction and implementation of new hi-tech solutions is complicated. Significant portion of biomass producers are family-owned business with pyramidal decision-making mechanisms, which makes the formation of new cooperation for technology transfer, the application of a new solutions, and the acceptance of related risks difficult.

Means to overcome: Through various activities conducted by the DIHs, the project increases awareness of the potential benefits offered by ICT, IoT, and Industry 4.0 within biomass supply chains, and helps forming multi-actor groups across the value chain to exploit innovation opportunities. Additionally, to overcome the reluctance, DIHs have a local approach, use communication tools in local languages and organise face-to-face meetings in order to stimulate direct communication. Relevant success stories will be highlighted to emphasize the positive impact, and to promote an open mind towards implementation of ICT, IoT, and Industry 4.0 solutions.

- Lack of understanding, i. e., high amount of information and disparity of specialised languages in each field of expertise

The project interconnects several diverse sectors, e.g., ICT, IoT, electronics, engineering, agriculture, food, biotechnology, forestry, etc. Hence, it is possible that due to the different languages (set of specific terms) that each sector is accustomed to, the common understanding could be reduced, and opportunities for win-win cooperation would be missed.

Means to overcome: The role of DIH competence centres are of paramount importance. They act as central node for connecting the different disciplines, supporting biomass suppliers and technology developers in communication and mutual understanding, as well as in identification of opportunities for ICT, IoT, and Industry 4.0 to increase the efficiency of biomass supply chains, and cooperation agreements.

- Conflicting regulations regarding biomass supply chains

Regulations for biomass management are different depending on the biomass source and destination as well as region. This may lead to obstacles adopting certain solution into new type of biomass or application area.

Means to overcome: ICT-BIOCHAIN considers the particularisation of applicable regulation and standards in each biomass supply chain and region when developing the DIH activities and drafting the roadmap for DIH replication. Moreover, as a point of contact, DIH may provide advices on regional specific requirements by means of its knowledge centre services.

6.1.2. Identified within the launch events of the Digital Innovation Hubs

Identifying the main needs and especially barriers was the primary objective of the inquiries carried out in both model demonstrator regions.

Questionnaires distributed during the DIH Launch events were customised for parties which already have and which have not yet implemented ICT, IoT, and Industry 4.0 technologies in their operations (see Appendix 1). The answers are grouped accordingly, and listed with respect to frequency, with which a particular answer appeared.

Reasons why ICT / IoT technologies have not been implemented yet

- Costs
- Lack of knowledge/awarness
- Lack of assistance
- Resistance/reluctance to changes
- Applications do not exist
- New/immature biomass subsector
- Planned only for new facilities

Obstacles faced during implementation of ICT / IoT technologies

- Lack of knowledge
- User training
- Adaptation
- Data (management, structure, keeping up-to-date)
- Continuous improvement
- Costs

Figure 6: Barrier and obstacles harnessing the implementation of ICT / IoT technologies

By comparing these two lists, it becomes apparent that lack of knowledge, as well as needs for investments, training, and acceptance and adaptation to changes are the main aspects that hinders implementation of new technologies in biomass supply chain. Costs, however, seem less critical to those who have already went through the process of adopting new solutions. Either financial resources of these parties mitigated the issue, or the gained benefits outweighed the incurred costs.

Additionally, participants of the Irish workshop were asked to rank the top-5 reasons for not implementing ICT, IoT, and Industry 4.0 solutions with respect to how strong the barriers are. The results are shown in below figure.

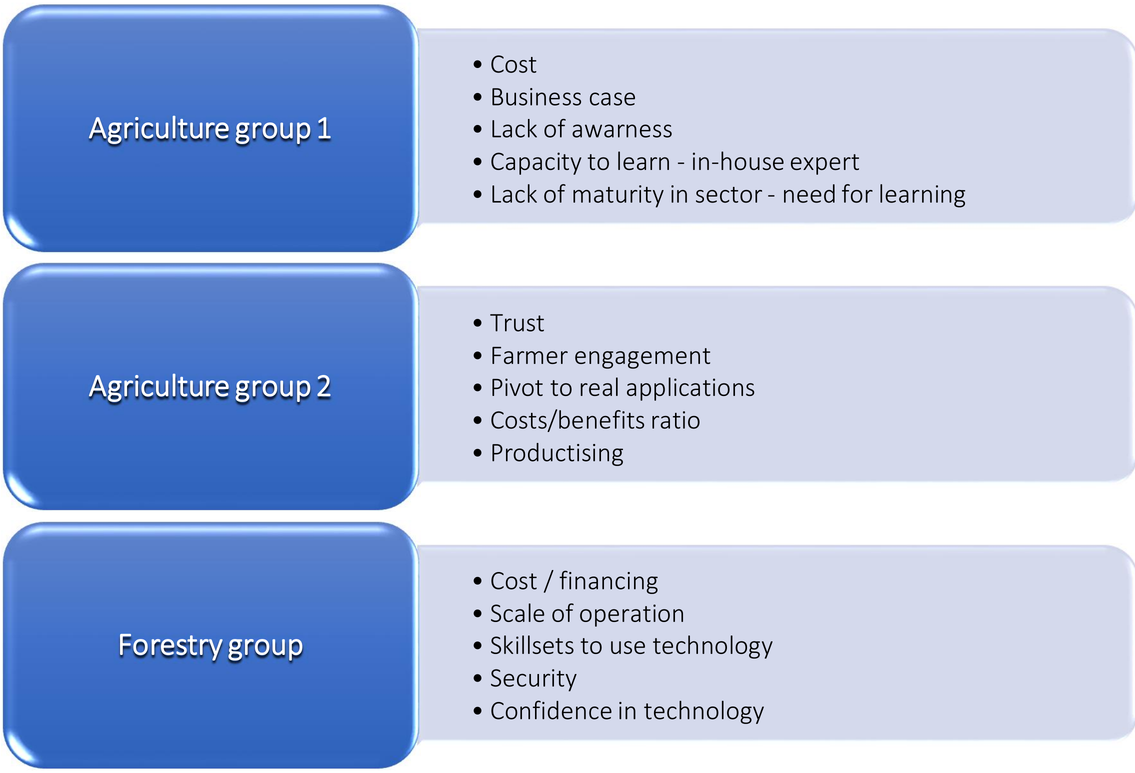

Figure 7: Technology implementation barriers ranked with respect to their severity

Similarly to outcomes of the questionnaires, many participants of the workshop expect high costs (or costs/benefits ratio) associated the implementation of innovative technologies. At this point, it is worth mention that 31% of questionnaire responders not using ICT / IoT technologies said that their organisation would not be able to finance the implementation of a new technology, while further 31% are not sure about that. Moreover, some stakeholders worry that the scale of their operations may be insufficient to justify the effort.

Another big group of obstacles relates to low awareness of available solutions and existing business case, distrust, and resulting low engagement of the stakeholders. Finally, lack of knowledge, lack of required skillset, and missing in-house technical expertise impose a significant hurdle on the way to adoption of new technological solutions.

Within the Andalusian workshop, participants listed the barriers in four different categories: distress and understanding difficulties, cultural aspects, economical aspects, and others.

Distress, understanding difficulties

- Bad experience from the past (efforts, which have not added value)
- Distrust of unproven technologies, feeling of being test object
- Technological Gap, lack of understanding, speaking different languages
- Difficult relationship and finding a common point
- Feeling that ICTs are "smoke sellers"

Cultural aspects

- Traditional processes little open to change
- The inertia of a sector anchored in established processes, resistance to change
- Ignorance of the existing technological offer, ignorance of the benefits that could bring
- Difficulty to grow together, except in the traditional cooperative model, which is not usually involved in the internal management of each cooperative

Economical aspects

- Granularity, small companies with little investment capacity
- Conception of technology as an expense versus investment, difficulty appreciating the added value that is provided
- High price of the available technological solutions
- High logistics costs, transport difficulties
- Too low business margin to allow investment without a guaranteed ROI

Others

- Doubts about the security of the information, which is contributed to a system, concerns to share data with others (a boss or a collaborator) - will they see something that they do not like or can use against me
- Uncertainty about regulations and legislation related to the management of waste and by-products. When I get involved, will I be breaking any regulations, will I be doing something wrong?
- Little valuation by the market of the environmentally responsible products, lack of promotion of the value and importance of an adequate management of biomass, waste, by-products

Figure 8: Classification of barriers into different aspect categories

Additionally, participants pointed out following possible remedies to reduce the impact of these barriers:

- Low-cost, packetized, scalable technological solutions that could be implemented simply and economically in biomass producers and consumers with low investment capacity, but which could already show benefits from the advancing technology
- Incentives (financing, fiscal, social, etc.) to responsible management
- Search for "joint" business models, through associations, cooperatives, groupings. Sale to a group of clients, so that the solution is profitable for everyone.

6.2. Needs for support from DIHs

Another task within the conducted workshops was to find out what hopes stakeholders have towards the new DIHs, what help they need, and what the DIH can do to support them. The participants stated their wishes divided into four categories of **technology**, **business**, **bioresources** and **others**, as listed below.

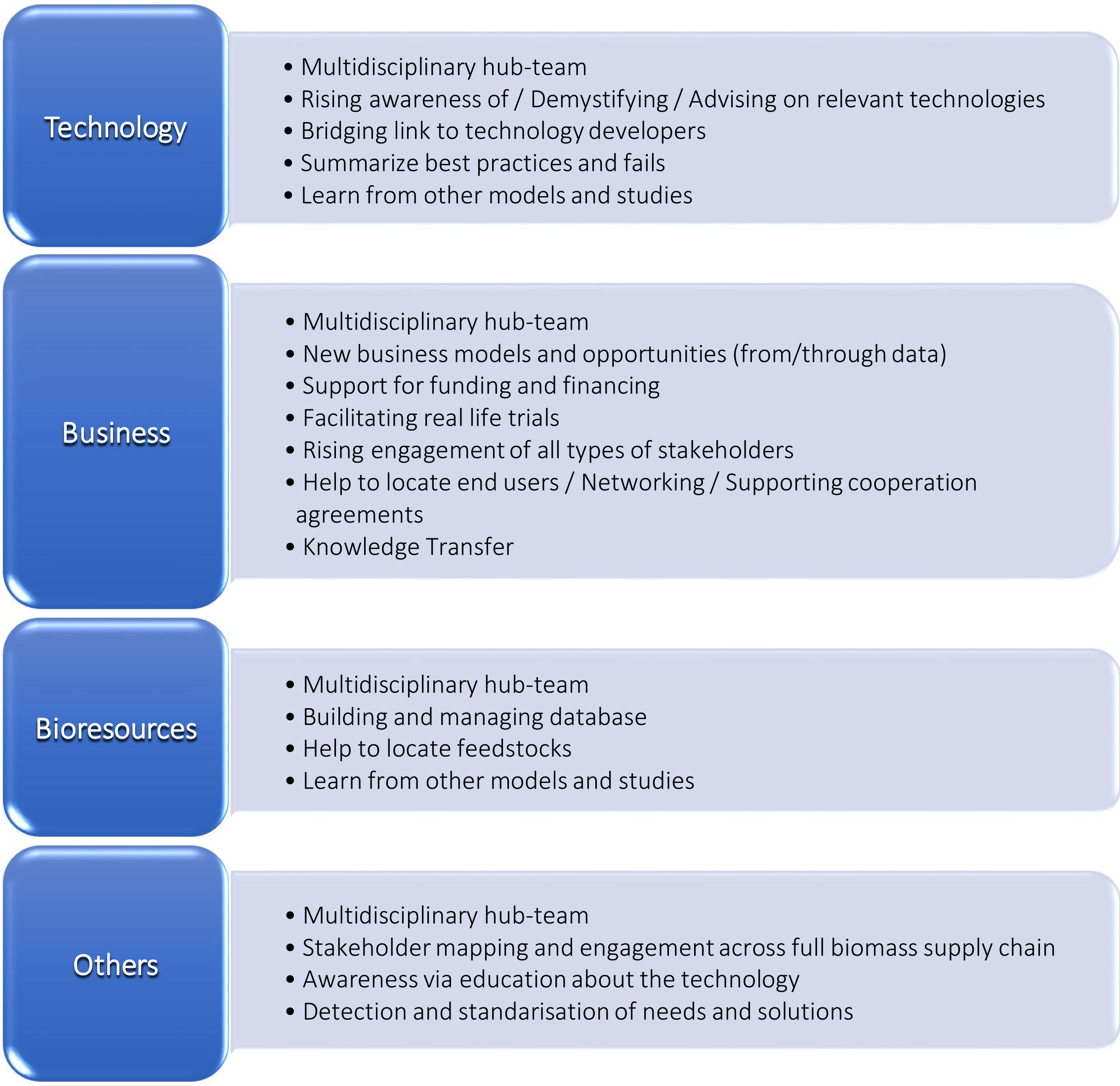

Figure 9: Identified needs regarding the Development of the DIHs

Generally, it is extremely important for stakeholders that the DIHs consist of multidisciplinary experts and covers all sectors of modern bioeconomy (technology, business/finance, bioresources etc.). In this way, DIHs can uncover the regional potential for new/increased bio-based activities and provide support in various aspects of their operations.

In terms of **technology**, stakeholders need a higher awareness of relevant technologies and their explanation in simple/understandable language in order to demystify them. DIHs certainly can provide such a support. Moreover, hub should serve as a bridging link between biomass producers/users and technology providers. Summarized lessons learned from other studies as well as examples of best practices, success stories and fails would be very interesting.

Concerning the **business**, DIHs could show and/or help develop new opportunities (through use of data) and business models (emphasizing the value of data). The engagement of stakeholders (biomass producers, users and technology providers) could be leveraged via facilitation of real-life trials, especially when assistance in search for funding would also be provided. Such trial projects as well as other DIH activities (conferences, demo days, knowledge transfer events) can help finding partners for cooperation, networking, and signing agreements.

Regarding **bioresources**, stakeholders see DIHs playing crucial role in creating, building and management of a common database helping in locating available feedstocks, their quantity and composition, either through testing or based on the knowledge gained from other models, studies, or regions.

Another database could provide a mapping of stakeholders and their engagement across the full value chain. DIHs could also provide educational materials about technologies, business opportunities, and best practises.

Further aspects and topics brought up during the discussions on future development of the hubs included:

- Project financing
- Research and Development
- Circular Economy
- Rural Development
- Valorising and using of forestry products in the bioeconomy
- Development of predicting models for biomass composition
- Biorefinery examples in rural areas
- Future foods (Algae etc.)
- Agro residues for primary users and post-processors.

7. Conclusions

Technological opportunities for improvement in biomass utilisation were sought for through analysis of the mapped technologies in D1.1 as well as based on the information provided by the participants of DIH launch events in Andalusia and SE-Ireland. With the help of questionnaires and workshops, the regional stakeholders had a chance to express their needs and to identify barriers that block the adoption of new technologies into their operation.

Several technologies have aroused stakeholders' interest due to their high potential for generating improvements in biomass supply chains. These solutions can be grouped in three main application categories:

- operation management (e.g., ERP, data analysis, traceability)
- quality control and process optimisation (sensor systems, monitoring tools)
- biomass availability/composition mapping/modelling, which could increase the utilisation of biomass through the existing or new supply chains.

However, many stakeholders do not invest in such technologies, because they are not aware of existing solutions and their benefits. They suspect large costs associated with the implementation/adoption and high level of expertise required from the user to operate them. Even the parties implementing technologies name the attitude, lack of knowledge, and costs as major obstacles faced during the process.

DIHs can help resolve most of these issues through the envisioned activities:

- providing information on existing solutions and their main features (technology database in ICT-BIOCHAIN platform, demo days)
- educating stakeholders (competence centre, knowledge transfer days, conferences, courses, e-learning material)
- organising networking events (DIH as contact point, meetings, assistance in cooperation)
- providing support in finding and applying for financial support.

Therefore, the DIHs play a crucial role in taking advantage of ICT, IoT, and Industry 4.0 technologies for improvement of biomass utilisation, and development of European bioeconomy.

8. References

[1] ICT-BIOCHAIN deliverable D1.1 "Assessment of the current ICT, IoT, and Industry 4.0 solutions in European biomass utilization"

[2] https://en.wikipedia.org/wiki/Enterprise_resource_planning

[3] https://en.wikipedia.org/wiki/SAP_ERP
http://www.businessdictionary.com/definition/SAP.html

[4] https://en.wikipedia.org/wiki/Geographic_information_system

[5] https://en.wikipedia.org/wiki/ArcGIS
https://www.esri.com/en-us/arcgis/about-arcgis/overview

[6] https://en.wikipedia.org/wiki/Machine_learning

[7] https://www.hispatec.es/en/

[8] https://hispatecanalytics.com/

[9] https://en.wikipedia.org/wiki/Closed-circuit_television

9. Appendix 1 - Questionnaire templates

ICT BIOCHAIN

Bio-based Industries Consortium

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

ICT, IoT and Industry 4.0 Needs and Opportunities in Biomass Supply Chain

Questionnaire for parties already implementing ICT / IoT technologies

Name of company / Institute / University (research group) etc.?		
What are the core activitites and aims of the company / Institute / University, etc.? (sector, working area)		
What kind of biomass does your organisation work with?		
Do you have access to ICT/IoT expertise in your organisation?	Yes ☐	☐ No
What ICT/IoT technology specific for biomass logistics / the supply chain of biomass do you use? Could you please describe the main features?		
Which are the main benefits and advantages of those ICT/IoT technologies?		
Are there any shortcomings in those ICT/IoT technologies?		
Please describe the main barriers and difficulties you have found when implementing / adopting those ICT/IoT technologies.		
If already used in biobased supply chains, could it also be used in other biobased supply chains? If so, which / how?		
Are there further areas of your supply chain or process could benefit from integration of new technology? Please Describe		
Other comments?		

Figure 10: Questionnaire for parties already implementing ICT, IoT, and Ind. 4.0 solutions

ICT BIOCHAIN

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ICT, IoT and Industry 4.0 Needs and Opportunities in Biomass Supply Chain

Questionnaire for parties NOT implementing ICT / IoT technologies

Name of company / Institute / University (research group) etc.?		
What are the core activitites and aims of the company / Institute / University, etc.? (sector, working area)		
What kind of biomass does your organisation work with?		
What part of the biomass (organic material) supply chain do you think could benefit from the integration of ICT technology?		
What are the reasons that you have not already implemented these ICT technologies?		
Do you have access to ICT/IoT expertise in your organisation?	Yes ☐	☐ No
Would your organisation be able to finance the integration of any ICT/IoT technology?	Yes ☐	☐ No
Other comments?		

Figure 11: Questionnaire for parties NOT implementing ICT, IoT, and Industry 4.0 solutions