



Deliverable 1.1.

Assessment of the current ICT, IoT, and Industry 4.0 solutions in European biomass utilization

Acronym: ICT-BIOCHAIN
Project title: ICT-BIOCHAIN - ICT Tools in Efficient Biomass Supply Chains for Sustainable Chemical Production
Contract N°: 79221
Start date: 1.6.2018
Duration: 24 months

Deliverable number	D1.1
Deliverable title	Assessment of the current ICT, IoT, and Industry 4.0 solutions in European biomass utilization
Submission due date	M9 – February 2019
Actual submission date	26/02/2019
Work Package	WP1
WP Lead Beneficiary	VTT
Dissemination Level	Public
Version	03
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This project has received funding from
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 introduces a collection of ICT, IoT and Industry 4.0 technologies utilized in Biomass Supply Chains that constitute current state-of-the-art along with their brief descriptions. The technologies are divided by the location of their applications into two categories:

- a) regional state-of-the-art describes solutions utilized in the involved demonstrator regions of Andalusia, Spain, and South-Eastern Ireland;
- b) Pan-European state-of-the-art describes solutions utilized in other regions of Europe.

This collection will later be used as an input for the ICT-BIOCHAIN platform. The list represents the current best knowledge of its creators. However, due to continuous technological progress, it is probably neither exhaustive nor very accurate yet in a near future. Therefore, in the ICT-BIOCHAIN platform, technology description will also provide information on the date of entry or last modification, and the platform will have capability for updating the information.

Content

1. Executive Summary.....	3
2. Acronyms and abbreviations.....	5
3. Introduction	6
4. Methodology and data sources	7
4.1. Regional data	7
4.2. Pan-European data.....	8
5. Regional state of the art	9
5.1. State-of-the-art in Andalusia Region	9
5.2. State-of-the-art in Irish Region	18
6. Pan-European state of the art.....	27
6.1. Basic technologies	27
6.2. Complex solutions and services.....	38
6.3. Online platforms and databases.....	68
7. Conclusions	80
8. References.....	83

2. Acronyms and abbreviations

ALS	Airborne Laser Scanning
B2B	Business-to-Business
BLE	Bluetooth Low Energy
GDPR	General Data Protection Regulation
GIS	Geographical Information System
GPS	Global Positioning System
HF	High Frequency (3...30 MHz)
ICT	Information and Communications Technology
IoT	Internet of Things
ISM	Industrial, Scientific and Medical frequency band
LF	Low Frequency (30...300 kHz)
MEMS	Micro-Electro-Mechanical System
NIR	Near-Infrared light range
NIRS	Near-Infrared Spectroscopy
RFID	Radio Frequency Identification
SWIR	Short Wave Infrared
TRL	Technology Readiness Level
UHF	Ultra-High Frequency (300 MHz ... 3 GHz)
UV	Ultra-Violet light range
VIS	Visible light range

3. Introduction

With the growing awareness of impact people's activity has on the environment, the bio-economy based on sustainable supply chains of alternative biomaterials gains a momentum. Additionally, scarce availability of some materials and/or price competition with traditional (less environment-friendly) approaches call for value maximization along the entire supply chain. That is where various ICT, IoT, and Industry 4.0 solutions come to aid.

Depending on the type of a biomass (wood, algae, hay, straw, etc.) and its final destination (timber, fodder, chemical refinery, biofuels, combined heat and energy generation), different sensor tools and monitoring platforms can be applied. Some applications might put emphasis on provenience of a biomass, its content or specific parameters, while others are also interested in reliable supply throughout the year.

Some technologies like radio frequency identification (RFID) or sensors for monitoring environmental conditions (humidity, temperature) can be applied throughout an entire supply chain, assuring the biomass quality, storage safety, and efficiency and reliability of the logistics. Meanwhile other tools might be useful only at a certain stage. For instance, growth rate and environment condition (soil humidity and pH) monitoring can help biomass producers to maximize the production by e.g., indicating a need of fertilization or optimal time for harvesting. Local storage providers can monitor water content of the biomass in order to avoid unnecessary load for transportation, while at the same time preserving the desired parameters, and thus quality and value of the biomass. Logistics providers can use location tracking to optimize their services (fleet management, communication with customers, etc.). Yet another group of ICT tools are the online databases and platforms, which can be crucial in forming new supply chains and optimizing those already existing. For example, they may include mapping data of the available and potential biomass resources, databases with specific knowledge or its providers, contact medium for stakeholders, and even online trading platforms.

As can be seen, there are plenty of opportunities within the biomass supply chains to take advantage of ICT, IoT and Industry 4.0 solutions. With growing market of biomass, rising the technological awareness among the stakeholders is essential to expand the applications of ICT tools for boosting the sustainability and efficiency.

This report is organized as follows. Section 4 describes the methodology and data sources utilized in collecting information. Section 5 focuses on the ICT, IoT and Industry 4.0 solutions utilized in biomass supply chains in the demonstrator regions (Andalusia, Spain and SE Ireland), while Section 6 expands to pan-European scope. Section 7 summarizes the work and draws some conclusions. Finally, Section 8 provides a list of the most important references.

4. Methodology and data sources

The mapping of the ICT, IoT, and Industry 4.0 technologies and solutions started with creating a common database format. Such an approach ensures the descriptions are uniform regardless of their origins - the same type of data is collected for applications within DIH regions and Europe-wide. The format includes specific inputs, which can help the user to filter data by state of art, such as TRL level and expected year of deployment, as well as cost estimates, and level of accessibility. Information is provided on the current and future application of the technology within specific biomass supply chains. Technical aspects and the benefits to the supply chain including the overall environmental impact are also included. Contact information is provided to facilitate collaboration with primary producers, bio-based industry and technology providers.

4.1. Regional data

In order to capture data on regionally available ICT, IoT and Industry 4.0 tools, which could be integrated within regional supply chains, a questionnaire form was developed by partners to specify the required data. This questionnaire ensures consistency between regional case studies and Pan-EU studies, and has been designed in a form that is suitable for upload to the ICT-BIOCHAIN platform in WP3.

In Ireland, a scoping was undertaken to identify key sources/ potential contributors to this deliverable including regional technology providers, research groups and projects under development, which involve the use/integration of ICT, IoT, and Industry 4.0 within biomass supply chains. To do this the partners carried out:

- an extensive search of relevant National projects
- a search of EU projects with regional relevance
- literature review
- consultation with various industry/research sources

Direct contact was then made with identified participants/initiatives (SME/industry/research) to highlight the ICT-BIOCHAIN project and its objectives, and participating organisations have supplied a description of their initiatives.

In Andalusia, a mapping of the different stakeholders that could contribute to the deliverable was conducted jointly by CAGPYDS (former CAPDER) and CTA. This was done considering: CTA cluster members, CAGPYDS (former CAPDER) and CTA network and literature review. To mitigate the risk of stakeholders not effectively engaged in the DIH, specific ICT sector characteristics were taken into account, for example potential reluctance for giving details about technologies' maturity levels, given the fact that ICT solutions have a very short cycle to reach the market. Hence, based on CTA internal know how in project fields, a small but representative group of relevant projects/ICT solutions providers were selected, registered in the Andalusian Stakeholder database, and CTA proceeded to retrieve the needed information.

In order to create and maintain a trustworthy environment, it was seen as necessary to provide a brief information about project objectives and context, how it will benefit the stakeholder, and why the requested information is relevant. Moreover, it was determined that an information about GDPR and the procedures of handling the gathered feedback should also be provided. To initiate, the most appropriate contact person for the information retrieval inside the stakeholder organisation was identified. In order to maximise efficiency and results expected from the interaction, contacting stakeholders was done in three steps. First, the person from ICT-BIOCHAIN partner organisation most familiar or more recently in touch with the specific stakeholder sent an email to make him/her aware that a colleague (name/position) would shortly contact him/her by email about a recently funded EU-project of their interest (include title of the project). Then, the person in charge of the information retrieval sent the email with information request. The general ICT-BIOCHAIN brochure, customised project dissemination material (when available), questionnaire, and GDPR consent were attached to the email. Finally, a phone-call round to stakeholders was done several times in order to retrieve the missing inputs.

4.2. *Pan-European data*

Data in the Pan-European state-of-the-art has been gathered by conducting:

- analyses of the reports from various European projects related to bioeconomy or its technological advancements (such as INDISPUTABLE KEY, FOCUS, INFRES, FOROPA, and many others);
- literature surveys;
- internet search;
- direct contact with stakeholders.

Tools and applications, which seemed abandoned after the related project has ended (no website, no response from the contact person etc.), were excluded from this collection. The inputs on commercial technologies and solutions offered by companies have been based on their descriptions from producers' websites.

The section on Pan-European state of the art has been divided into three subsections:

- basic technologies are the fundamental building blocks usually combined with other techniques to form a complete solution of a certain issue;
- complex solutions and services involve more than one basic technology (e.g., sensing and communications), and are typical for commercial offerings;
- online platforms and databases are the services providing information, contacts to potential business partners, marketplaces or any combination of these.

5. Regional state of the art

5.1. State-of-the-art in Andalusia Region

Name / ACRONYM	IDAB-IIoT
Company / R&D / Academia	Integra Factory Desarrollo SL
Contact person	info@idab-iiot.es
General information	IDAB-IIoT is a hardware platform for easily connecting machines or industrial assets to the Internet of Things (IoT) opening a gate to Industry 4.0 applications. Our new Kits Smart Monitoring consists of a packed solution with minimum installation for monitoring machines health.
Operational status / TRL	TRL 9-
Country	Spain
Into service	Currently in service. Actually, they are developing new models using data from the devices to implement predictive maintenance solutions.
Website	http://idab-iiot.es/
Publications	N/A
Extra info	IDAB-IIoT can collect information from any kind of industrial sensors and send this information to any cloud platform via wireless.
Subsector	Industry 4.0
Area of current application	Manufacturers and energy producers. Agrifood.
Process steps	N/A
Benefits	Condition monitoring reduces machine stops around 70%.
Potential areas of application	This technology can be use in biomass transformation process.
Cost per unit	Around 3000€ including sensors.
Environmental impact	N/A
Level of accessibility	Our devices can send information from sensors to any cloud platform via API. We also offer a cloud solution for monitoring machine health/status.

Name / ACRONYM	Smart Brain
Company / R&D / Academia	Wellness Telecom
Contact person	http://www.wtelecom.es/contacto/?lang=en
General information	Smart Brain is a Big Data and Analytics platform devoted to collect data from multiple sources, analyse it, and provide information in order to assist in the decision making of different players involved.
Operational status / TRL	TRL 7
Country	Spain
Into service	TRL 7 was reached in 2017 for some sectors, in agroindustry the platform is foreseen to run by the end of the year 2019 with new added value.
Website	http://www.wtelecom.es/welcome/
Publications	N/A
Extra info	New specific information will be available in the web soon.
Subsector	Smart Brain involve IoT, ICT and Industry 4.0 concepts
Area of current application	Mainly in Smart Cities sector
Process steps	<ol style="list-style-type: none"> 1. Study of specific needs of a concrete sector or industry. 2. Plan the sensors required to obtain the information as well as the ICT infrastructure to collect all the data in a reliable way. 3. Deploy the sensors and homogenize the data collected to be processed by SmartBrain. 4. The platform will learn about the normal operation processes to generate enough historic information to apply machine learning algorithms in order to optimize them. 5. Once the platform has enough information can generate valuable information to decision makers to increase the productivity of their industries. A specific dashboard will be available at this step to received alerts and advices for managers and other players.
Benefits	<ul style="list-style-type: none"> • Decreases the time required in decision making. • Horizontal, interoperable, scalable, flexible and modular platform. • Real-time and historical data analysis. • Logging of multiple user profiles with permissions adapted to the needs of each role. • Data mining, Machine Learning and operational data engineering. • Dynamic and customizable data exploitation layer by the users, definition of KPIs and customized visualizations. • Creation of simulated environments, what-if analysis to obtain the optimal point of operation.
Potential areas of application	From Wellness Telecom perspective, this horizontal platform add value to bioeconomy supply chains. It helps to optimize any process as data will be processed to obtain valuable information.
Cost per unit	Wellness Telecom normally follows a Software and Knowledge as a Service to generate recurrent incomes.
Environmental impact	Smart Brain helps to reduce carbon footprint of the industry as this processes optimization derives in better dimensioning of resources and waste reduction.
Level of accessibility	The platform consist of a web service accessible by all the required players involved, from this platform the users can obtain of the specific information from all the sensors and data collected.

Name / ACRONYM	New technologies based on blockchain to manage the identity, reliability and traceability of transactions of goods and services (service chain).
Company / R&D / Academia	SOLTEL IT Solutions SLU
Contact person	http://www.soltel.es/en/contactar/
General information	Soltel is on charge of the development of a prototype about the creation of a general blockchain platform for traceability in industry 4.0.
Operational status / TRL	TRL5-6 at the end of the project, by June 2020
Country	Spain
Into service	2020
Website	N/A
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Industry 4.0 / Agro / Pharma
Process steps	not defined yet
Benefits	Depends on the use case, but in general the benefits of blockchain technology applied to supply chain.
Potential areas of application	Any that involves a supply chain: agrifood, pharma, industrial, aeronautical...
Cost per unit	It is delivered as a service with an initial investment in consultancy and process adoption (maybe some IT infrastructure like IoT will be necessary). The initial investment depends on the specific sector, but several sectorial profiles will be developed to reduce initial costs. After that, a monthly fee, that will be based on the number of transactions carried out, will be issued.
Environmental impact	not evaluated
Level of accessibility	The system provides read only access to all the information generated, through a series of dashboards and planning tools delivered in a cloud platform.

Name / ACRONYM	System for the enhancement of the olive tree cultivation by means of hyperspectral technology and the application of the new technologies (SACROPS). Also, have similar developments for industry tomato and vines.
Company / R&D / Academia	SOLTEL IT Solutions SLU
Contact person	http://www.soltel.es/en/contactar/
General information	We use hyperspectral images and machine learning, combined with data coming from drones, soil humidity sensors and weather stations to monitor productivity and maturity parameters of the crops and to detect common plagues in early stages.
Operational status / TRL	TRL 5
Country	Spain
Into service	2020
Website	http://www.soltel.es/en/sacrops/
Publications	N/A
Extra info	https://www.ctaex.com/transferencia-tecnologica/sacrops
Subsector	Industry 4.0
Area of current application	Agriculture. We have started with olive tree crops, and we are now adapting the technology for tomatoes and vines.
Process steps	<ul style="list-style-type: none"> • Installation of sensors, beacons and communication infrastructure on the field before the season starts • Collection of specific data of the plot and the crop (geographical data, variety, transplanting date, etc) • Periodical monitoring sessions with the drone taking pictures at different heights • Periodical monitoring sessions with the hyperspectral camera, taking pictures of selected sample trees/branches/plants • Data integration, cleaning and analysis
Benefits	<p>Efficiency improvement due to the optimization of the monitoring tasks during the season, using a non-destructive and no time consuming technique.</p> <p>Performance improvement of the crops thanks to optimal use of watering, fertilization and phytosanitary products.</p> <p>Performance improvement of the crops through optimal harvesting time to enhance quality and production parameters.</p>
Potential areas of application	Agriculture: olive trees, industrial tomatoes and vines. Potentially customizable for any kind of crop.
Cost per unit	It is delivered as a service with an initial investment in equipment and a regular fee during the season. The cost of the installation depends on the plot surface and required sensors and communications infrastructure (that may differ in each particular plot). The monthly fee also depends on the extension of the plot and the frequency of the monitoring sessions (the more often the more reliable the results).
Environmental impact	<p>Reducing water consumption and use of fertilizers and phytosanitary products.</p> <p>In certain crops, like industrial tomatoes, reducing waste (green or over-ripen fruits are rejected).</p>
Level of accessibility	The system provides read only access to all the information generated, through a series of dashboards delivered in a cloud platform.

Name / ACRONYM	Smart system for prediction and routes optimization in solid urban waste collection
Company / R&D / Academia	SOLTEL IT Solutions SLU
Contact person	http://www.soltel.es/en/contactar/
General information	Smart-RSU is a platform that provides predictive information about how full a specific container will be in the near future, within a scope of 7 days, based on historical waste collection data and contextual additional information.
Operational status / TRL	TRL 5
Country	Spain
Into service	2020
Website	http://www.soltel.es/en/smart-rsu-soltel-participa-en-un-proyecto-de-investigacion-para-el-desarrollo-de-un-sistema-inteligente-de-prediccion-y-optimizacion-de-rutas-para-la-recogida-de-residuos-solidos-urbanos/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Smart Cities
Process steps	<ul style="list-style-type: none"> • Installation and calibration of sensors in the trucks if they don't already have them, and communications infrastructure • Collection of specific data about the city: number and type of containers, location (if known), local conditions (general rules and SLA), waste disposal sites, etc. • Data gathering in a control area for fine tuning the predictive algorithms • Normal full scale operation • Yearly recalibration and fine tuning
Benefits	Efficiency improvement due to the optimization of the collecting routes. Only containers that need to be emptied are visited. Savings in fuel and working hours. Accurate forecasting to enhance planning.
Potential areas of application	Logistics of materials collection in a distributed network.
Cost per unit	It is delivered as a service with an initial investment in equipment and a monthly fee. The cost of the installation depends on the availability of sensors in the trucks, number of trucks and communications infrastructure. The monthly fee also depends on the number of trucks and containers.
Environmental impact	Reducing fuel consumption, CO2 emissions and noise pollution.
Level of accessibility	The system provides read only access to all the information generated, through a series of dashboards and planning tools delivered in a cloud platform.

Name / ACRONYM	Foodintegrity
Company / R&D / Academia	Research group "Engineering of agricultural and livestock production systems" (ISPAG). ETSIAM, UCO (Universidad de Cordoba)
Contact person	https://secure.fera.defra.gov.uk/foodintegrity/index.cfm?sectionid=4
General information	The Work Package we are involved in , framed within the Topic "Rapid, on-site, cost-effective methods for feed/food fraud detection", aims at designing a system of "voluntary labelling" based on Near Infrared Spectroscopy (NIRS) in combination with information and communication technologies (ICTs) to be used in the Iberian Pig industry sector.
Operational status / TRL	TRL 5
Country	Spain
Into service	We expect the technology to become into service in 5 years
Website	https://secure.fera.defra.gov.uk/foodintegrity/index.cfm#
Publications	http://foodintegrity2017-parma.eu/wp-content/uploads/2017/05/FoodIntegrity.book_of_abstract.Conference.2017.pdf
Extra info	
Subsector	ICT, IoT
Area of current application	Meat industry, Agrifood
Process steps	<ol style="list-style-type: none"> 1. Selection of the instrument and the analysis mode (optical design, modes of analysis, place where the analysis are going to be made, etc. Especially taking into account that the market is now offering instruments for on-line and in-line analysis or instruments for in situ analysis with portable and miniature devices) 2. Spectral data acquisition 3. Reference data (information can be quantitative — contents of moisture, protein, fat, starch, aminoacids, sugars, texture values, etc.— or qualitative — as commercial category, variety, species, etc.) 4. Calibration/training population (Selection of samples for the calibration set may be performed using mathematical population-structuring tools and choosing the most representative samples) 5. Data pre-processing (to extract relevant chemical information from each sample, it is necessary to use spectral-signal pre-treatments which allow purely chemical information to be separated from variations of physical origin) 6. Calibration development using multivariate analysis (calibration is defined as the development of a prediction model that relates spectral data for the samples comprising the training set to the values provided by the reference method for the parameter in question.) 7. Outlier detection during calibration development (during calibration passes, outliers, i.e. samples that have unusually high residuals it can be detected, based on the use of different statistics enabling to identify samples which could represent an extrapolation of the model) 8. Validation of the models (the basis of the validation is the comparison of results obtained by analysis of the same set of samples by the NIRS and reference methods) 9. Routine analysis and recalibration (once the models developed have been validated and the results are positive according to the statistic protocol criteria, these models can be used for routine analysis for the prediction of new unknown samples)
Benefits	NIRS can record spectra for solid and liquid samples with no pre-treatment, implement continuous methodologies, provide spectra quickly and predict physical and chemical parameters from a single spectrum. These attributes make it especially attractive for straightforward, speedy characterization of samples.

Potential areas of application	Every field that include organic materials
Cost per unit	Portable instrument + calibrations = 80.000 Euro aprox.
Environmental impact	NIRS does not require sample preparation or additional reagents. Hence, the technology has no environmental impact.
Level of accessibility	High level of accessibility

Name / ACRONYM	Olivia - Olive Oil Production and Supply Chain Optimization tool
Company / R&D / Academia	Easytosee Agtech S.L. (ec2ce)
Contact person	https://www.ec2ce.com/contact-us/
General information	Olivia is a tool that help the farmer to: 1, optimize the irrigation and fertilization throughout the campaign; 2, integrated predictive pest control system; Market predictive at regional level
Operational status / TRL	TRL 7
Country	Spain and Portugal
Into service	Mediterranean region, California , Australia and Chile
Website	https://www.ec2ce.com
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Agricultural and food supply chain
Process steps	<ol style="list-style-type: none"> 1. Log in through the internet 2. Introduce some historical data 3. Introduce periodically data 4. Receive recommendations
Benefits	<ul style="list-style-type: none"> • Increase productivity • diminish water use • limit fertilizer applications • diminish pesticide applications
Potential areas of application	Production of olive pitsç
Cost per unit	Less than 1% of total production costs
Environmental impact	Reduce CO2 emissions / reduce N applied to the land / reduce N leaked to water / reduce pesticides
Level of accessibility	Accessible worldwide to the sector

Name / ACRONYM	The role of sensors and bio-imaging in monitoring and sustainable decision-making in bio-energy crops (ViewMass)
Company / R&D / Academia	University of Sevilla (ETSIA). Smart Biosystem Laboratory (AGR-278)
Contact person	N/A
General information	Current mapping technologies, UAV-borne LiDAR and multispectral cameras features prominently, with superior ability to resolve 3D vegetation structure calculations and assess biomass and bioproducts derived.
Operational status / TRL	Currently in TRL4 with the possibility to go TRL5 and TRL6 faster.
Country	Spain
Into service	End of 2019
Website	N/A
Publications	https://doi.org/10.3390/s18041242
Extra info	The challenge is to use LiDAR and UAV technology (multispectral + RGB) to be able to estimate biomass in order to optimize logistics and management in the connected industry and reduce atomization and uncertainty in the supply and transformation chain.
Subsector	IoT and Industry 4.0
Area of current application	Precision Agriculture / Digital Farming
Process steps	<ol style="list-style-type: none"> 1. Sensor (LiDAR + Multispectral Cameras) integration in airborne UAV platforms and flight performance for biomass data collection 2. Vehicles transporting biomass raw material will be monitored using IOT GPRS/GPS modules in which information on the load they are transporting is integrated in real time, using load measuring cells, sending the information directly to a cloud server. In this way, in real time the industry can know the state of the raw material that is going to reach the transformation chain, where it comes from and other relevant aspects. 3. Data collected will be sent from wireless collecting units to a central cloud server, where insights will be obtained regarding actual production, location, quality and forecasts of expected volume for logistics decision-making. 4. Information will be directly sent from the online platform to the 4.0 industry, where data aggregation will involve also real-time data from vehicles (trucks and heavy machinery) to fit the processes in the industry to real demand and real production.
Benefits	Being able to obtain information about biomass or bioproducts in advance, even with automatic learning elements, allows an improvement in efficiency with respect to the current state of management of these resources, which results in considerable savings for both the producer and the rest of the supply chain. Through the monitoring and connectivity of the vehicles in charge of supply, and the connectivity of industry 4.0 through an online platform accessible by both agents, it is easier to match the needs and supply, which minimizes losses.
Potential areas of application	The connectivity and sensing of the vehicles themselves plays a key role in the remote operation using this type of material, so that stock breakage can be avoided, biomass traceability can be generated and a technical itinerary useful for the industry. Currently, this is being applied in sustainable farming in order to control all the chemical applications and fertilizer inputs to avoid overtreatments and promote sustainable practices.
Cost per unit	"LiDAR sensor: 5000€ Multispectral camera: 3000€ UAV and integration: 4000€ IoT module for connectivity of supply chain vehicles: 450€

	Platform for data integration and analysis: 8000€"
Environmental impact	Vehicle monitoring in real time can enable controlled traffic strategies that drive to a reduction in CO2 emissions. Also the intelligence layers on the platform can contribute to decision-making in terms of allocation of the production/transformation, in order to increase the aggregation on the industry (minimizing the atomization problem) to reduce environmental impact of the activity.
Level of accessibility	An open API will be developed in order to achieve closer collaboration with other stakeholders in the adoption of this suite of monitoring solutions for the industry. IoT modules for vehicle monitoring in real time is not envisaged to be accessible due to the possible existence of industrial property conflicts.

5.2. State-of-the-art in Irish Region

Name / ACRONYM	Freshbox
Company / R&D / Academia	IMaR (IT Tralee), Fundación Aula Dei (PCTAD), Fundación AITIIP, KÖLLA Valencia SL, La Fuente Tomey, Transfer Consultancy
Contact person	Dr. Pat Doody, IMaR, 0872170063, pat.doody@ittralee.ie
General information	The Integrated Sensor Kit was developed to monitor some key physical properties inside a transportation container during a logistics phase.
Operational status / TRL	TRL 7
Country	Ireland
Into service	Project dependent - a full pilot has been completed successfully - 2017
Website	http://fresh-box.info/en/
Publications	N/A
Extra info	N/A
Subsector	IoT and ICT
Area of current application	Fresh Produce Transportation
Process steps	<ol style="list-style-type: none"> 1. The ISK is placed in the transportation container. 2. The ISK is paired with a mobile phone/Bluetooth enable laptop and the trip is configure and the sensor box is made active. 3. The ISK monitors through the transportation. 4. When the transportation is complete, the data is download to an app and the data is made visible for analysis.
Benefits	<ol style="list-style-type: none"> 1. Minimising losses in the supply chain 2. With some customisation could be used for remote monitoring also.
Potential areas of application	Environmental monitoring where required. The platform can be customised to include sensors not already on the ISK if necessary.
Cost per unit	€450 to €550 in its current form, would decrease in cost with a higher production volume.
Environmental impact	Depending on the application area the Integrated Sensor Kit unit has the potential to reduce waste by monitoring environmental conditions. For the Freshbox application, the application was monitoring fresh produce (fruit/veg) during the transportation phase.
Level of accessibility	Accessible through Bluetooth or USB connection. The data downloaded is accessible through a cloud based app.



freshBOX

Fig: Sensor Kit developed in Freshbox

Name / ACRONYM	Rapid Biomass Analysis
Company / R&D / Academia	Celignis Biomass Analysis Laboratory (SME)
Contact person	Dr. Dan Hayes, Celignis Biomass Analysis Laboratory, email: dan@celignis.com , phone: (+353) 61 518 440
General information	Rapid analysis method for the determination of lignocellulosic properties of biomass samples.
Operational status / TRL	TRL 9
Country	Ireland
Into service	2015
Website	https://www.celignis.com/index.php
Publications	DOI: 10.1016/j.biortech.2012.05.137; 10.1039/C7FD00081B; 10.1016/j.fuel.2015.01.094
Extra info	https://www.celignis.com/NIRanalysis.php
Subsector	ICT (Modelling)
Area of current application	Energy Crops, Agricultural Residues and Wastes, Industrial Residues and Wastes, Municipal Wastes, Biorefinery Products, Seaweed, Bio-oil
Process steps	<ol style="list-style-type: none"> 1. Pre-treatment - prior to analysis biomass is ground to a particle size less than 850 microns 2. Scanning - Biomass is scanned using Near-infrared spectroscopy. Near Infrared Spectroscopy (NIRS) provides a rapid means to analyse a wide variety of feedstocks. 3. Modelling and Analysis-Celignis has developed unique proprietary models that 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
Benefits	<p>Rapid Analysis: typically a one day turnaround time upon receipt of sample</p> <p>Lower Cost: The NIR method involves less laboratory work than the wet-chemical analytical methods which results in lower costs</p> <p>Effective Sample Screening: As a result of the increased speed and reduced cost of analysis the NIR method allows a far greater number of samples to be analysed than would otherwise be possible with standard methods.</p>
Potential areas of application	Potential for software to be used in industrial settings (e.g., within biorefinery/bioenergy facilities).
Cost per unit	60-150 \$/€ per sample
Environmental impact	Can help technology providers select the best feedstocks and/or process conditions, so maximising process efficiencies
Level of accessibility	Models and equipment are internal within Celignis's lab. However, Celignis can also develop and licence customised models that clients can use at their own sites.

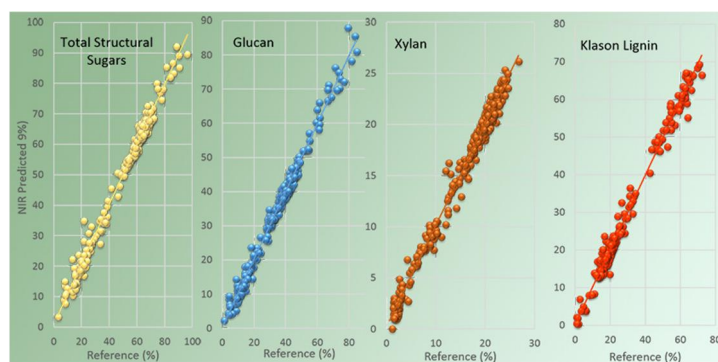


Fig: Celignis Analytical's logo and an example of analysis results.

Name / ACRONYM	"Life cycle assessment of biomass-to-energy systems in Ireland modelled with biomass supply chain optimisation based on greenhouse gas emission reduction"
Company / R&D / Academia	University College Dublin
Contact person	Dr. Fionnuala Murphy, UCD, Phone: +353 1 716 7317 Email: fionnuala.murphy@ucd.ie
General information	The project uses tactical and spatial optimisation model to determine the optimal biomass supply that satisfies the energy demand at a power plant, combining GIS and linear programming with life cycle assessment to optimise biomass supply chains.
Operational status / TRL	N/A
Country	Ireland
Into service	N/A
Website	http://www.ucd.ie/biosystems/
Publications	https://www.sciencedirect.com/science/article/pii/S036054421630545X
Extra info	N/A
Subsector	Data Analysis/Data modelling (ICT)
Area of current application	Forestry/Forestry residues
Process steps	<ol style="list-style-type: none"> 1. Biomass resource assessment - modelling of potentially available forestry resources for energy production, including pulpwood, brash bundles, stumps, miscanthus and willow 2. Life cycle assessment - Comprehensive life cycle studies are carried out on the production of each of the biomass feedstocks considered 3. Environmental impact Assessment is conducted taking into account AP (acidification potential) expressed in kg SO₂-equivalents, EP (eutrophication potential) expressed in kg PO₄-equivalents, and GWP (global warming potential) expressed in kg CO₂-equivalents. 4. Use of tactical and spatial optimisation modelling is then used to determine the optimal biomass supply that satisfies the energy demand at demand locations under different scenarios. The model displays the results in a series of matrices including among others: <ul style="list-style-type: none"> • Energy content (GJ) of each biomass material supplied to the demand location. • Number of truckloads delivered to the demand location. • GWP from production of each type of biomass and the corresponding GWP from biomass transportation. • Total transportation distances from each biomass supply point to each demand point.
Benefits	Modelling numerous supply chain scenarios ensures biomass supply is optimised with minimal GHG emissions.
Potential areas of application	The model is currently being applied to waste plastic supply chains and can be applied to the analysis of any biomass supply chain.
Cost per unit	N/A
Environmental impact	Potential to evaluate and reduce factors including global warming potential, acidification potential and eutrophication potential through optimisation of biomass supply.
Level of accessibility	The analysis is carried out using a number of different software packages; ArcGIS, Excel, and SimaPro. It is possible that the inventories could be populated with data from an IOT device or sensor.

Name / ACRONYM	Brash to bioproducts (MarEI)
Company / R&D / Academia	National University of Ireland Galway and Coillte
Contact person	Dr. Rory Monaghan, Lecturer of Mechanical Engineering, College of Engineering and Informatics National University of Ireland Galway Tel: +353 (0)91 494256 Email: rory.monaghan@nuigalway.ie
General information	Integrated process model-GIS-LCA to determine optimum supply chain for bioproducts derived from forestry residues in Ireland. Multi-criteria decision analysis is used to optimize biorefinery siting.
Operational status / TRL	TRL 6-7
Country	Ireland
Into service	2020
Website	http://www.nuigalway.ie/therme/
Publications	none as of yet
Extra info	N/A
Subsector	Data modelling (ICT)
Area of current application	Forestry and Chemicals sectors
Process steps	<ol style="list-style-type: none"> 1. Assess and map available suitable feedstocks (from census data) into GIS software, producing heatmaps of resource availability 2. Assess and map demand sites for potential products (including production and use location of potential chemicals) 3. Modelling the conversion and upgrading process (using a chemical engineering process model of conversion technologies) allowing sizing and costing of each piece of equipment 4. Use multi-criteria decision analysis (MCDA) to select optimal biorefinery location 5. Carry out an LCA of chosen supply chain configuration (using lca database information)
Benefits	Mobilising currently unutilised waste product
Potential areas of application	Other biobased/bioenergy products, different geographical locations, various biomass feedstocks
Cost per unit	N/A
Environmental impact	Offsetting fossil use in the chemical industry and reducing CO2 emissions
Level of accessibility	Potential for internet accessibility

Name / ACRONYM	Modelling Performance Characteristics of Biomass Haulage in Ireland for Bioenergy Markets with GPS, GIS and Fuel Diagnostic Tools.
Company / R&D / Academia	University College Dublin
Contact person	Dr. Amanda Sosa, Waterford Institute of Technology (formerly UCD), Ph +353 87 2146058: Email: Amanda.Sosa@wit.ie; amanda.sosa@ucdconnect.ie
General information	Analysis of characteristics of timber trucking in Ireland, to estimate the least-cost route for the distribution of biomass with the use of Geographic Information Systems.
Operational status / TRL	TRL 4
Country	Ireland
Into service	This technology is not in service and is not expected to become in service
Website	http://www.ucd.ie/biosystems/about/ourpeople-researchstaff/2/
Publications	https://pdfs.semanticscholar.org/d55c/3e52830dcc26213133124dba6d0bf1855fd2.pdf?_ga=2.153292920.1359199148.1540562309-1382608304.1540562309
Extra info	This study was funded by CoFoRD Forest Energy Programme 2008/RD (National Council for Forest Research and Development in Ireland) and under the Charles Parsons Energy Research Program (Grant Number 6C/CP/E001) of Science Foundation Ireland (www.sfi.ie).
Subsector	ICT
Area of current application	Forestry biomass
Process steps	<ol style="list-style-type: none"> 1. Analysis of Road Network: A digital road network of Ireland was used within the GIS for this study 2. Integration of Fleet management system: A fleet tracking system called R: COM provided by the service platform of Blue Tree was used in this study. consisted of a tracking system connected to the controller area network (CAN)-bus from the fleet management system (FMS) gateway on the truck's engine. It has a GPS tracker positioned on the outer side of the dashboard so that it becomes visible through the front windscreen. The GPS Blackbox is fitted with a standard mobile phone SIM card and positional Latitude and Longitude. Information is recorded by the GPS and sent via the global system for mobile communications/general packet radio service (GSM/GPRS) phone network to the data servers. The system reports vehicle's start up (ignition on) and shut down (ignition off) times, location, total travelling times, idling time and fuel consumption. The truck movements can be viewed in real-time and data are downloaded by logging online into the Blue Tree system 3. The recording interval of the truck's position from the GPS was 1 min; these recordings were saved as an Excel file. The Excel files contained the truck's positions as a series of columns indicating the Longitude (X, or Easting) and Latitude (Y, or Northing) in decimal number format. These data were converted to shapefiles where each GPS position point was transformed to a feature point using the Data Management Tool available in ArcGIS. GPS data are most often recorded in a geographic coordinate system world geodetic system (WGS) 1984 datum in this study), and with the use of the Projections and Management Tool also available in ArcGIS it was transformed to a projected coordinate system (TM65 Irish National Grid in this study) in order to be integrated to the Irish road network map. Map projection allowed the correct alignment of data from different spatial references within GIS for linear analysis such as distance and positional accuracy to the underlying road network.

	<p>4. After creating the network dataset the NA wizard was added to ArcMap's interface in order to create travelling routes. Feature class attributes like distance and legal maximum speed limits were used by NA to determine travel time per road segment. The routes taken by the truck driver (truck) and recorded by the tracking system were compared in terms of travelling time, distance and cost and use of the different road types with alternative routes simulated by NA. Different scenarios based on the criteria for determining the alternative routes were analysed including:</p> <ul style="list-style-type: none"> ● route based on the least accumulative distance travelled on the road network ● routes based on the less required travelled time ● routes based on shortest distance routes while prioritising travelling on higher-class roads (in order to minimize the expenses associated with road maintenance, a weighting has been applied to higher class roads) ● routes based on shortest time while prioritising travelling on higher-class roads. <p>Cost analysis: Assigning costs to truck transportation on different scenario routes taken into account those costs that are independent of the transportation distance and costs that depend on distance</p>
Benefits	Provide insight on optimal haulage route for biomass with opportunity to choose the lowest cost option. The lower the kilometres travelled per litre of diesel, the higher the fuel consumption, resulting in increased cost per kilometre and thus decreased revenue per kilometre (also the higher fuel consumption the greater environmental impact).
Potential areas of application	This methodology can be used to assess and improve the transportation of any other type of biomass or bio-based product. This tool can be potentially used on the planning of agreed routes for heavy transport with local councils as they are responsible of maintaining regional and local roads.
Cost per unit	N/A
Environmental impact	Potential to reduce CO2 emissions by choosing the optimal transport route. Fuel consumption by trucks is one of the largest contributors of greenhouse gases (GHGs)
Level of accessibility	The sensors and tracking system on the truck were provided by a company and requires payment of monthly fees. The routing algorithm is accessible via ArcGIS which require a license for its use.

Name / ACRONYM	"Managing the moisture content of wood biomass for the optimisation of Ireland's transport supply strategy to bioenergy markets and competing industries"
Company / R&D / Academia	University College Dublin
Contact person	Dr. Amanda Sosa, Waterford Institute of Technology, (Formerly UCD), Ph: +353 87 2146058 Email: Amanda.Sosa@wit.ie; amanda.sosa@ucdconnect.ie
General information	Development of linear programming model to optimise tactically the wood biomass supply chain in Ireland. Model aids decision making on harvest, storage and optimal truck loads for dispatch, based on moisture content of biomass
Operational status / TRL	TRL 4 - TRL 5
Country	Ireland
Into service	This Excel based tool is currently not in service.
Website	http://www.ucd.ie/biosystems/about/ourpeople-researchstaff/2/
Publications	https://www.sciencedirect.com/science/article/pii/S0360544215004867
Extra info	This study was funded by CoFoRD Forest Energy Programme 2008/RD (National Council for Forest Research and Development in Ireland) and under the Charles Parsons Energy Research Program (Grant Number 6C/CP/E001) of Science Foundation Ireland (www.sfi.ie).
Subsector	ICT
Area of current application	Forestry biomass
Process steps	<ol style="list-style-type: none"> 1. Identification of demanding points (power plants/mills) for wood delivery and potential wood supply (private forests) 2. Estimation of truck transport distances from supply to demand points using a digital road network of Ireland. 3. Collection of parameters for a range of supply chains (including chipping, logs from clearfell and thinning respectively). Parameters include harvesting, forwarding and chipping costs. It also provided basic density, bulk density and bulk-solid volume conversion factor data, net calorific value and average truck's volume and weight capacity data, storage costs 4. Collection of in-forest drying information (wood moisture content) 5. Tactical and spatial optimisation using Linear Programming to determine the optimal wood supply to different demand locations while minimising supply costs. The model displays the results in a series of matrices including among others: <ul style="list-style-type: none"> • Decision variables on tonnes and corresponding solid volume of wood to be harvested in each period (two year planning). • Loose volume (lv) of wood chips produced at the roadside in each period. • Weight of the wood (logs and wood chips) to be supplied to the peat plants and board panel mills. • Number of truck loads delivered to the power plants and panel mills. • Energy content of wood chips in gigajoules (GJ) arriving at the power plants. • Harvesting, forwarding, chipping, storage, and transportation costs.
Benefits	Model aids decision making on: - where, when and how to harvest forest biomass; - for how long to dry wood in-forest in order to reach a high calorific value demanded by power plants, and - what type of truck configuration to use and which wood product is more cost-effective to transport in terms of energy units delivered (bundles vs wood chips, etc.)

Potential areas of application	The tool is not currently used within the biobased sector. The model was tailored to forestry supply chains, but the principles and methodology can be applied to any other biomass supply chain
Cost per unit	N/A
Environmental impact	Supports optimal supply chain making biomass supply chain a more viable alternative to fossil energy. Potential for reducing delivery truck trips, thereby reducing GHG emissions.
Level of accessibility	This is an Excel based tool. The optimisation algorithm is provided by a third party company and requires a licence in order to run the model.

Name / ACRONYM	Bio-SNG in Ireland - Marei Funded
Company / R&D / Academia	National University of Ireland Galway, Gas Networks Ireland
Contact person	Dr. Rory Monaghan, Lecturer of Mechanical Engineering, College of Engineering and Informatics National University of Ireland Galway Tel: +353 (0)91 494256 Email:rory.monaghan@nuigalway.ie
General information	Integrated process model-GIS-LCA to determine optimum supply chain for biomass-derived synthetic natural gas (bio-SNG) in Ireland. Initial feedstocks of interest are: forestry residues, cereal residues, sewage sludge, digestate, municipal solid waste. Currently investigating forestry waste in greater detail.
Operational status / TRL	TRL 6-7
Country	Ireland
Into service	N/A
Website	http://www.nuigalway.ie/therme/
Publications	https://www.sciencedirect.com/science/article/pii/S136403211830683X
Extra info	N/A
Subsector	Data analysis/Data modelling (ICT)
Area of current application	Forestry residues, cereal residues, sewage sludge, digestate, municipal solid waste to Bio-SNG (renewable natural gas)
Process steps	<ol style="list-style-type: none"> 1. Assess and map available suitable feedstocks (census data) into GIS software, producing heatmaps of resource availability 2. Assess and map demand locations of end product (location AGI 's of natural gas grid - injection points) 3. Modelling the conversion and upgrading process (chemical engineer process model of conversion technologies) allowing sizing and costing of each piece of equipment 4. Optimisation of conversion site location to minimize overall costs of energy produced 5. LCA of chosen supply chain configuration (lca databases)
Benefits	Aids decision-making in planning and sizing Bio-SNG plants, exportable/transferable technology
Potential areas of application	Hydrogen, Biochemicals
Cost per unit	N/A
Environmental impact	Full LCA, CO2 emissions reduced, reducing waste (black bin waste)
Level of accessibility	Potential for internet accessibility

Name / ACRONYM	GENCOMM - GENERating energy secure COMMunities through Smart Renewable Hydrogen (Interreg N.W.E funded project)
Company / R&D / Academia	Viridian Energy Supply Limited, Williams Industrial services, Pure Energy Centre, National University of Ireland Galway, IZES GmbH, ENSICAEN, INSA Rouen Normandie, TK Renewables, BURN Joint Research Group, Vrije Universiteit Brussel.
Contact person	Dr. Rory Monaghan, Lecturer of Mechanical Engineering, College of Engineering and Informatics National University of Ireland Galway Tel: +353 (0)91 494256 Email:rory.monaghan@nuigalway.ie
General information	Online map-based decision support tool (DST) to guide investments in hydrogen storage of renewable energy. Includes process modelling, GIS and multi-criteria decision analysis
Operational status / TRL	TRL 6
Country	North Western EU - Ireland, UK, Fr, Ger, Benelux
Into service	2020
Website	http://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/
Publications	http://www.nweurope.eu/media/3517/gencomm-smart-h2-positon-paper-march-2018.pdf
Extra info	N/A
Subsector	ICT (data modelling)
Area of current application	1. Power Generation and 2. Transport
Process steps	<ol style="list-style-type: none"> 1. Mapping availability of curtailed renewable energy in N.W.E. (i.e. wind and solar) 2. Mapping demand for hydrogen as a transport fuel, industrial feedstock and Natural Gas lending agent (injecting Hydrogen to the grid) 3. If high quality data is available for particular region then there is detailed process modelling and an optimized hydrogen storage site is selected based on minimum cost of energy 4. If high quality data is not available, multi-criteria decision analysis (MCDA) is used to select potential storage site 5. Provide recommend next steps in realising a hydrogen storage site (policy, funding etc.)
Benefits	Derisking the development of Hydrogen energy storage by helping to select optimum storage locations
Potential areas of application	Could be source of Hydrogen for biogas upgrading
Cost per unit	N/A
Environmental impact	Offset fossil fuel use in transport and reduce wasted renewable energy (reduce overall CO ₂).
Level of accessibility	Will be publicly available and accessible online for all persons at end of project.



Fig: GenComm project header

6. Pan-European state of the art

6.1. Basic technologies

Name / ACRONYM	Satellite positioning
Company / R&D / Academia	Solutions available from multiple vendors
Contact person	N/A
General information	Satellite positioning systems allow localization and tracking of the receiver (or an objects equipped with receiver) location. These systems include the US operated GPS , European Galileo and Russian GLONASS . A timing signal transmitted by satellites is used to determine the 3D location of the receiver by precisely measuring the timing difference of the signals from several satellites and thus the distance to them. With the known position of the satellites, the receiver position can be calculated typically within 1-10 m. The precision of the positioning can be improved by combining the location data from several positioning systems or by using differential techniques where a land station with known locations transmits a correction signal to help the receivers to locate themselves with higher precision.
Operational status / TRL	TRL 9
Country	worldwide
Into service	2005 (assisted GPS in mobile phones)
Website	https://www.gps.gov/
Publications	N/A
Extra info	Satellite positioning systems can be used to locate and tracking of items. It also allows geotagging, i.e., marking the location at which a certain item (e.g., biomass lot) was harvested/packaged/etc.
Subsector	IoT
Area of current application	Forestry, logistics
Process steps	N/A
Benefits	Monitoring the origin and track of a biomass supply.
Potential areas of application	Throughout the whole chain
Cost per unit	N/A
Environmental impact	May be used for proving the biomass provenience, and thus limit the illegal harvesting
Level of accessibility	Each receiver can individually be located and tracked.

Name / ACRONYM	RFID - Radio Frequency Identification
Company / R&D / Academia	Commercially available tags and readers from multiple vendors
Contact person	Look for contacts through providers' websites
General information	Radio-frequency identification (RFID) uses electromagnetic fields to identify and track tags attached to objects.
Operational status / TRL	TRL 9
Country	Available and used in logistics worldwide. UHF RFID was applied to forestry in Finland and Sweden.
Into service	'90s
Website	https://idesco.fi/ https://www.nordicid.com/ https://www.impinj.com/ https://www.smartrac-group.com/
Publications	https://en.wikipedia.org/wiki/Radio-frequency_identification https://www.electronics-notes.com/articles/connectivity/rfid-radio-frequency-identification/what-is-rfid-technology-basics.php http://www.diva-portal.org/smash/get/diva2:962552/FULLTEXT01.pdf https://www.sciencedirect.com/science/article/pii/S0166361513000572 https://www.sciencedirect.com/science/article/pii/S0925527316300342 https://www.sciencedirect.com/science/article/pii/S0924224416304198 https://www.sciencedirect.com/science/article/pii/B9780081005965031644
Extra info	The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a battery and may operate hundreds of meters from the RFID reader. The tag need not be within the line of sight of the reader, so it may be embedded in the tracked object. Reading distance depends on used frequency band: LF (120–150 kHz): 10 cm, low data rate HF (13.56 MHz): 10 cm–1 m, low to moderate data rate UHF (865–868 MHz in Europe): 1–12 m, moderate to high data rate
Subsector	IoT/Industry 4.0
Area of current application	Forestry, logistics, food supply chains
Process steps	1. installation of readers at the desired locations 2. attaching tags to items 3. database correlating IDs with items
Benefits	Product or person identification and tracking or access restrictions. Fast wireless reading at the gates etc. Can be combined with simple sensors (e.g., temperature) for condition monitoring.
Potential areas of application	Throughout the whole chain
Cost per unit	Tags: ~0.10€, Readers: x00€...>2000€, depending on frequency (LF, HF, UHF), features, and manufacturer
Environmental impact	Can be used to: - assure the provenience - aid in reducing the biomass degradation - retain the biomass maximal value
Level of accessibility	Directly accessible with reader

Name / ACRONYM	QR code - Quick Response code
Company / R&D / Academia	Standard. Commercially available code generators and readers. QR code reading applications are also free available for smartphones (camera works as a scanner).
Contact person	google play app store
General information	The QR code is one of the most-used types of two-dimensional optical code. QR codes are now used in both commercial tracking applications and convenience-oriented applications aimed at mobile-phone users (mobile tagging). Within the “EuroPruning” project, the QR codes were used for traceability along with sensor units within the smart logistics system for biomass from pruning supply chain. Within the project “Indisputable Key”, similar types of coding were developed in Sweden and Estonia for timber supply chains.
Operational status / TRL	TRL 9
Country	Japan, worldwide
Into service	Developed in 1994. Similar 2D codes are used in wood supply chains.
Website	https://en.wikipedia.org/wiki/QR_code
Publications	https://cordis.europa.eu/docs/results/312/312078/final1-europruning-final-report-publishable-summary.pdf http://www.diva-portal.org/smash/get/diva2:962552/FULLTEXT01.pdf https://www.mdpi.com/2076-3417/8/7/1162
Extra info	N/A
Subsector	ICT
Area of current application	Logistics, forestry
Process steps	N/A
Benefits	Product or service identification. Fast and easy information sharing. Free.
Potential areas of application	Throughout the whole chain
Cost per unit	free alternatives available for code generators and readers (smartphone app)
Environmental impact	Can be used to: - assure the provenience - aid in reducing the biomass degradation - retain the biomass maximal value
Level of accessibility	Directly accessible with reader or smartphone (camera as a scanner)



Fig: Example of QR code representing author's contact information (business card).

Name / ACRONYM	NIRS - Near-Infrared spectroscopy
Company / R&D / Academia	Widely used in industry, medical and agriculture
Contact person	N/A
General information	Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum. It can be used to assess various properties of materials or objects. NIR is widely applied in agriculture for determining the quality of forages, grains, and grain products, oilseeds, coffee, tea, spices, fruits, vegetables, sugarcane, beverages, fats, and oils, dairy products, eggs, meat, and other agricultural products. Within the INFRES project, the NIR technique was demonstrated for assessment of moisture content in wood chips. Within the RECOMBIO project, the NIR-device was used for online analysis of Cl content in solid recovered fuels.
Operational status / TRL	Generally TRL 9 In moisture measurements of wood chips TRL 5, In Cl-content assessment TRL 7-9
Country	worldwide
Into service	N/A
Website	https://en.wikipedia.org/wiki/Near-infrared_spectroscopy
Publications	https://plantsciencesweb.missouri.edu/roberts/research/NIRmonograph.pdf https://www.intechopen.com/books/developments-in-near-infrared-spectroscopy/using-near-infrared-spectroscopy-in-agricultural-systems https://cordis.europa.eu/project/rcn/104506/reporting/en https://dl.sciencesocieties.org/publications/books/tocs/agronomymonograph/nearinfraredspe
Extra info	NIR spectroscopy can also be applied for remote investigation of plants and soils. Data can be collected from instruments on airplanes or satellites to assess ground cover and soil chemistry.
Subsector	IoT
Area of current application	Wide application in agriculture
Process steps	N/A
Benefits	accurate, reliable, rapid, non-destructive, and inexpensive
Potential areas of application	agriculture, assessment of biomass properties at any stage in the chain
Cost per unit	N/A
Environmental impact	May lead to more efficient biomass use, reduced transportation costs and emissions.
Level of accessibility	N/A

Name / ACRONYM	Bluetooth
Company / R&D / Academia	Standard maintained by Bluetooth Special Interest Group
Contact person	Solutions provided by many vendors
General information	Bluetooth is a short-range wireless technology for fixed and mobile devices to transmit and receive data. The operating frequency is 2.4-2.48 GHz within the industrial, scientific and medical (ISM) band. The communications are using a packet-based protocol with a master/slave architecture where one master may communicate with up to seven slaves.
Operational status / TRL	TRL 9
Country	worldwide
Into service	1990s
Website	https://www.bluetooth.com/
Publications	https://en.wikipedia.org/wiki/Bluetooth https://www.electronics-notes.com/articles/connectivity/bluetooth/what-is-bluetooth-technology-basics-summary.php
Extra info	Bluetooth operating range depends on the power class: <ul style="list-style-type: none"> • Class 1: 100 mW, ~100 m. • Class 2: 2.5 mW, ~10 m. • Class 3: 1 mW, ~1 m. • Class 4: 0.5 mW, ~0.5 m. Bluetooth low energy (BLE) provides reduced power consumption and cost while maintaining the communication range using the same ISM bandwidth by using the frequency different. The data rate is lower than with the regular Bluetooth. The protocol is not compatible with the ordinary Bluetooth. In 2017, the Bluetooth mesh networking protocol based upon BLE that allows for many-to-many communication over Bluetooth radio has been developed and adopted.
Subsector	ICT, IoT
Area of current application	Home/office/fitness devices, industrial sensor networks
Process steps	N/A
Benefits	Standardized, inexpensive, phone, tablet or computer can act as a hub master
Potential areas of application	Sensor networks within confined area (e.g., storage house)
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Individual devices are paired to master

Name / ACRONYM	WiFi
Company / R&D / Academia	WiFi Alliance
Contact person	Many companies provide Wi-Fi based solutions
General information	Wi-Fi is technology for radio wireless local area networking of devices based on the IEEE 802.11 standards. Commonly used to provide wireless access to the internet via dedicated access points (hotspots). The coverage range from a single room/apartment up to many square kilometres achieved with multiple hotspots.
Operational status / TRL	TRL 9
Country	Available worldwide
Into service	N/A
Website	https://www.wi-fi.org/
Publications	https://www.electronics-notes.com/articles/connectivity/wifi-ieee-802-11/what-is-wifi.php
Extra info	Different versions of Wi-Fi exist, with different ranges, radio bands and speeds. Wi-Fi most commonly uses the 2.4 GHz UHF and 5.8 GHz SHF ISM radio bands; these bands are subdivided into multiple channels. Each channel can be time-shared by multiple networks. These wavelengths work best for line-of-sight. Many common materials absorb or reflect them, which further restricts range, but can tend to help minimise interference between different networks in crowded environments. At close range, some versions of Wi-Fi, running on suitable hardware, can achieve speeds of over 1 Gbit/s. Wi-Fi is a trademark of the Wi-Fi Alliance.
Subsector	IoT
Area of current application	Home/office or citywide wireless internet access.
Process steps	N/A
Benefits	Standardized, inexpensive, and widely available hardware.
Potential areas of application	Production or final user facilities
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Depending on implementation

Name / ACRONYM	LoRa - Long Range
Company / R&D / Academia	SEMTech
Contact person	https://www.semtech.com/company/contact
General information	Digital wireless data communication technology using license-free sub-gigahertz radio frequency, connecting IoT sensors to the Cloud and enabling real-time communication of data and analytics that can be utilized to enhance efficiency and productivity. LoRa enables very-long-range transmissions (more than 10 km in rural areas) with low power consumption.
Operational status / TRL	TRL 9
Country	France, USA, network operating in 51 countries
Into service	N/A
Website	https://www.semtech.com/lora
Publications	https://www.semtech.com/lora/resources/lora-white-papers https://www.electronics-notes.com/articles/connectivity/lora/what-is-lora-basics-m2m-iot.php
Extra info	Proprietary protocol, thus its free documentation is not available. Services/solutions provided by companies - members of LoRa-alliance (country-specific).
Subsector	IoT
Area of current application	smart agriculture, natural resource management, renewable energy, logistics, and supply chain management
Process steps	N/A
Benefits	LoRa Technology offers an efficient, flexible and economical solution to real-world problems in rural and indoor use cases, where cellular and Wi-Fi/BLE based networks are ineffective. LoRa and LoRaWAN permit inexpensive, long-range connectivity for Internet of Things (IoT) devices in rural, remote and offshore industries.
Potential areas of application	Throughout the whole chain
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Depending on particular implementation

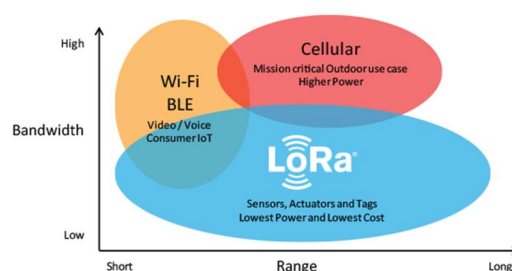
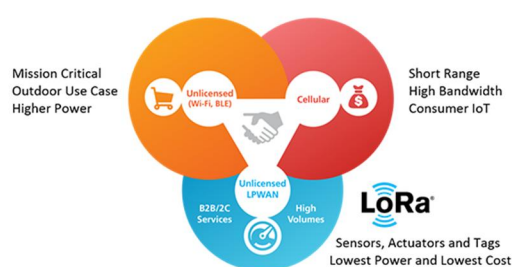


Fig: LoRa is complementary/alternative to other communications solutions (image source: <https://www.semtech.com/lora/why-lora>)

Name / ACRONYM	Sigfox
Company / R&D / Academia	Sigfox
Contact person	Through website: https://www.sigfox.com/en/about-us/contact
General information	Sigfox is a global network operator that builds wireless networks dedicated exclusively to connect low-power IoT devices, providing their monitoring and tracking.
Operational status / TRL	TRL 9
Country	France
Into service	2009
Website	https://www.sigfox.com/en/
Publications	https://www.link-labs.com/blog/sigfox-vs-lora https://www.electronics-notes.com/articles/connectivity/sigfox/what-is-sigfox-basics-m2m-iot.php
Extra info	Applied to logistics and supply chains allows you to: track your assets to optimize the supply chain, monitor transport conditions throughout the entire supply chain, improve safety of the goods, improve warehouse security, recover stolen vehicles quickly. In agriculture application you can: precisely monitor weather conditions, virtually fence, track and manage herds, collect soil condition data, monitor silo and tank levels, measure the temperature of grain stocks, protect remote farmhouses and outbuildings, secure gates and deter livestock thieves, optimize colony health with remotely monitored beehives, monitor food temperatures along the entire cold chain.
Subsector	IoT
Area of current application	Agriculture, supply chains and logistics, manufacturing and others
Process steps	N/A
Benefits	<i>In agriculture:</i> remote access to real-time information about rainfall, temperature changes, wind conditions, air pressure, and humidity at the precise location. Enables optimization of labour, water usage and crop health (precision agriculture). <i>In logistics:</i> flexible, affordable, and an end-to-end view of the supply chain in real time. Easy monitoring of the location and condition of goods as they travel by land, sea, and air, improved security for warehouses and fleet vehicles.
Potential areas of application	Throughout the whole chain
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Devices accessed through software tools.

Name / ACRONYM	3G / 4G LTE / 5G - Mobile communications
Company / R&D / Academia	Offered/operated by multiple companies
Contact person	Your local operator or IoT/sensor solution provider
General information	Cellular mobile communications system providing broadband data capacity. Each consecutive generation (introduced in around decade intervals) aims at ~100 times faster transfers than the previous one, usually by employing new higher frequency bands and reducing the distance between base stations. Can be utilized as a gateway providing access to a hub of sensors in a very distant location.
Operational status / TRL	3G and 4G are TRL 9, 5G is at TRL 6-7
Country	worldwide
Into service	2000s
Website	http://www.3gpp.org/
Publications	https://en.wikipedia.org/wiki/Cellular_network https://en.wikipedia.org/wiki/3G https://en.wikipedia.org/wiki/4G https://en.wikipedia.org/wiki/5G https://www.electronics-notes.com/articles/connectivity/3g-umts/what-is-umts-wcdma-tutorial.php https://www.electronics-notes.com/articles/connectivity/4g-lte-long-term-evolution/what-is-lte-basics-tutorial-overview.php https://www.electronics-notes.com/articles/connectivity/5g-mobile-wireless-cellular/technology-basics.php
Extra info	Especially, the upcoming 5G is supposed to be the backbone for worldwide IoT, natively providing simultaneous network access for billions of devices.
Subsector	ICT, IoT
Area of current application	Remote sensor stations
Process steps	N/A
Benefits	Standardized technology with multiple stakeholders providing rapid development and competitive pricing.
Potential areas of application	5G could provide links for devices throughout the whole chain.
Cost per unit	Depends on technology, implementation, and service providers.
Environmental impact	N/A
Level of accessibility	Depends on implementation

Name / ACRONYM	Blockchain
Company / R&D / Academia	"Satoshi Nakamoto"
Contact person	N/A
General information	Blockchain is a decentralized, distributed and public digital ledger that is used to record transactions across many computers so that any involved record cannot be altered retroactively, without the alteration of all subsequent blocks. This allows the participants to verify and audit transactions independently and relatively inexpensively. A blockchain database is managed autonomously using a peer-to-peer network and a distributed timestamping server.
Operational status / TRL	TRL 9
Country	Japan
Into service	2008
Website	N/A
Publications	http://graphics.reuters.com/TECHNOLOGY-BLOCKCHAIN/010070P11GN/index.html
Extra info	N/A
Subsector	ICT
Area of current application	Cryptocurrencies, smart contracts, banking, agrimarket
Process steps	N/A
Benefits	Highly secure by design
Potential areas of application	Biomass market and transactions
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	ALS - Airborne Laser Scanning
Company / R&D / Academia	Solutions provided worldwide by multiple vendors. For instance in Europe the hardware is offered by: <ul style="list-style-type: none"> - Aerolaser System S.L. (Spain) - Aeroscout (Switzerland) - GeoLas Consulting (Germany) - IGI (Germany) - Riegl (Austria)
Contact person	Contact representative of a respective company
General information	Airborne Laser Scanning (ALS) systems are LiDAR systems which can be mounted on aerial vehicles such as airplanes, helicopters, and drones. The LiDAR (Laser Imaging Detection and Ranging) technology enables the automated acquisition of 3-dimensional data at a high rate. Weather and visibility hardly affect measurements, making these systems ideal for any surveying, inspection or mapping.
Operational status / TRL	TRL 9
Country	worldwide
Into service	N/A
Website	http://www.aerolaser.es/en/index.php https://www.aeroscout.ch/ http://www.geolas.com/Pages/indexE.html https://www.igi-systems.com/home.html http://www.riegl.com/
Publications	https://www.sciencedirect.com/science/article/pii/S0924271699000118
Extra info	ALS can be combined with e.g. GSP 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).
Subsector	IoT
Area of current application	Precision agriculture, forestry, and many industrial and scientific uses
Process steps	N/A
Benefits	Can be used to optimized use of fertilizers or harvesting.
Potential areas of application	Biomass production or availability mapping
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

6.2. Complex solutions and services

Name / ACRONYM	HYDRA100 Scout
Company / R&D / Academia	Soil Scout Oy
Contact person	http://soilscout.com/contact/
General information	Soil Scout provides critical insight into data from deep below the surface wirelessly. It is a patented, small, cost-effective wireless sensor platform that depending on conditions, transmits near real-time data for up to 20 years, and at a depth of up to 2m (~6ft) underground: maintenance free.
Operational status / TRL	TRL 9
Country	Finland
Into service	2015
Website	http://soilscout.com/solution/
Publications	http://soilscout.com/documents/
Extra info	Soil Scout was initially developed with Agriculture in mind, and our current HYDRA100 Scout has integrated moisture, temperature and salinity sensors. Nowadays, multiple industry sectors are benefiting from the ability to easily and continuously monitor their own below-ground environments, regardless of season or weather conditions (agriculture, compost bulk measurement, golf course irrigation management, concrete structure moisture detection or embankment monitoring).
Subsector	IoT
Area of current application	Agriculture, Sports Venues, Golf Courses
Process steps	N/A
Benefits	Benefits of the Soil Scout solution can include: <ul style="list-style-type: none"> • Water and energy savings of up to 50% • Decreased fertiliser loss • Optimised soil conditions • Reduced pollution • Lower maintenance costs Increased land utilisation
Potential areas of application	Forestry & Biomass, Mining, Security and Defence, Construction and Infrastructure, Road Monitoring, Viticulture, Buried Utilities
Cost per unit	Contact a suitable dealer: http://soilscout.com/sales/
Environmental impact	Water savings, pollution reduction.
Level of accessibility	Via the platform

Name / ACRONYM	HAYTECH
Company / R&D / Academia	Quanturi
Contact person	Nadine Pesonen (nadine.pesonen@quanturi.com), info@quanturi.com
General information	HAYTECH is a wireless monitoring system for your hay. The handy probes are connected to the internet, allowing you to follow the real-time temperature of your hay effortlessly.
Operational status / TRL	TRL 9
Country	Finland
Into service	2015
Website	https://quanturi.com/pages/haytech
Publications	N/A
Extra info	N/A
Subsector	IoT
Area of current application	Farming
Process steps	1. Install the system, 2. Place the probes Check on your hay whenever you want from your phone, tablet or computer. You also get SMS alert if temperature starts rising.
Benefits	Possibility to remotely (online) check the state of you haystack, assuring its quality is preserved and diminishing the risk of a spontaneous fire burst.
Potential areas of application	Biomass producers and storages
Cost per unit	650,00 € - HAYTECH10 set including 10 wireless HAYTECH probes, base station device, Quanturi online service that includes alert messaging and visualization. Additional probes sold separately with unit prices depending on the quantity: https://quanturi.com/pages/shop-haytech
Environmental impact	Maximize the quality, value and efficient usage of biomass. Reduces the risk of fire and the numbers of travels to distant storage places.
Level of accessibility	Individual probes can be followed via online platform



Fig: QUANTURI and HAYTECH logos and the HAYTECH10 kit.

Name / ACRONYM	Quanturi monitoring systems
Company / R&D / Academia	Quanturi
Contact person	Nadine Pesonen (nadine.pesonen@quanturi.com), info@quanturi.com
General information	Quanturi monitoring system is a wireless temperature monitoring system for composting or for storage of biomass (grain, woodchip, peat) or other materials (e.g., waste)
Operational status / TRL	TRL 9
Country	Finland
Into service	2018
Website	https://quanturi.com/pages/compost https://quanturi.com/pages/grain
Publications	N/A
Extra info	Separate versions of the solutions optimized for grain monitoring and for composting are readily available. Take a direct contact for other biomass storage.
Subsector	IoT
Area of current application	Farming
Process steps	1. Install the system, 2. Place the probes Follow the temperatures whenever you want from your phone, tablet or computer.
Benefits	Helps to preserve quality, assures compliance with regulations (documenting temperatures over time becomes easy), increases work safety (less contact with dangerous fumes), saves money (fans run only when needed).
Potential areas of application	Biomass producers and storages or composting units
Cost per unit	Ask for the quotation
Environmental impact	Maximize the quality, value and efficient usage of biomass. Reduces the risk of fire and the numbers of travels to distant storage places.
Level of accessibility	Individual probes can be followed via online platform

Name / ACRONYM	Greenhouse Technology (Heat Reuse, Vertical Farming)
Company / R&D / Academia	Novarbo Oy
Contact person	See: https://www.novarbo.fi/en/contacts.html
General information	The Novarbo Greenhouse Technology system includes greenhouse cooling, climate control, moisture removal and heat reuse. As a new hardware application, a Vertical Farming solution that combines all areas of the system is offered.
Operational status / TRL	TRL 9
Country	Finland
Into service	1994
Website	https://www.novarbo.fi/en/greenhouse-technology.html
Publications	N/A
Extra info	N/A
Subsector	Industry 4.0
Area of current application	Farming, agriculture
Process steps	N/A
Benefits	Water cooling increases led lighting lifetime, significant annual energy savings, fresh water savings, shorter growing period, higher yield per m ² . Often more economical solution compared to new heat power investment with payback time even less than one year.
Potential areas of application	Farming
Cost per unit	Contact sales
Environmental impact	Energy and fresh water savings, increased crop yield per square meter
Level of accessibility	N/A

Name / ACRONYM	GrainSense
Company / R&D / Academia	GrainSense
Contact person	Edvard Krogus, CEO, edvard.krogus@grainsense.com
General information	Grain quality measurement system based on near-infrared spectroscopy for on-spot tests with laboratory level accuracy. The system includes measurement device, smartphone application and cloud services.
Operational status / TRL	TRL 9
Country	Finland / Germany
Into service	2018
Website	https://www.grainsense.com/
Publications	https://www.grainsense.com/community
Extra info	Currently operates for 4 grain species: Wheat, Barley, Oats and Rye. Additional species are planned for near future.
Subsector	IoT
Area of current application	Agriculture, farming
Process steps	N/A
Benefits	Helps making confident decisions based on actual data regarding harvesting, quality/price estimations, silos management, optimization of feed blends for livestock.
Potential areas of application	Testing and assurance of grain quality throughout the whole chain
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Measurement data available directly on the device or from the cloud (e.g., historical data) through a smartphone app.

Name / ACRONYM	CarbonToSoil
Company / R&D / Academia	CarbonToSoil
Contact person	contact@carbontosoil.com
General information	CarbonToSoil is a mobile application with mission to reverse climate change by putting carbon back to the soil through regenerative agriculture approaches. CarbonToSoil is a non-profit project and it targets consumers and responsible businesses and communities. Via application anyone can convert a plot of land from a Finnish or global (in the near future) farm, and monitor weather data and see how the crops are growing through images. Users can also follow the soil conversion progress from lab analysis and in the future also from soil sensor data. The users will learn more about regenerative agriculture approaches and in the near future, they may also potentially command the application of additional carbon sinks, add trees and plants with long roots and much more.
Operational status / TRL	Estimated TRL 4-6
Country	Finland
Into service	2015
Website	http://www.carbontosoil.com/
Publications	http://www.carbontosoil.com/en/facts.html#links
Extra info	N/A
Subsector	IoT
Area of current application	Farming, agriculture
Process steps	<ol style="list-style-type: none"> 1. A farmer dedicates a small sized plot for the use of the pilot service. We are looking for particularly problematic plots. Within these plots, the farmer has not applied organic agriculture or regenerative farming practices. Please note that in dry land agriculture supplemental irrigation and water harvesting are needed to minimize production risks. Please inform us which type of soil could be allocated for this pilot project. 2. Size of a plot in Finland: 5-20 ha (12-50 acres). (Other countries; the minimum and maximum size requirement is yet to be determined). 3. Willingness to experiment with new approaches. 4. Possible installation of soil sensors into different depths, e.g. 15, 25 cm. The need for sensors will be decided on case by case basis. 5. Participating in a web based training session: regenerative farming approaches. We will also organize "face to face" training sessions. 6. Signing a pilot contract between Cohu Entertainment and the farmer. Carbon to Soil -pilot is implemented during June 18th 2015 – March 31st 2016. We will reserve an option to extend the contract by 2–5 years, until to 2020. The contract includes items such as responsibilities, requirements and key duties. 7. Periodic reporting of the applied regenerative farming approaches.
Benefits	<ul style="list-style-type: none"> ● In Finland, a financial support is provided, about 100 euros per ha, for the duration of the first growing season. A possible continuation of financial assistance will be decided after the pilot period. Financial support is only available to very problematic fields/plots. In regards to other countries, the financial support will be decided on a case by case basis. ● Cohu offers free education and training services to get the farmers started. We will also connect the participating farmers in order to facilitate the exchange of best practices. ● Cohu pays for one field sample per year from the plot dedicated to the CarbonToSoil project. The field sample measures the amount of carbon stored in the soil and analyses the status of key nutrients. The

	<p>initial field sample analysis direct the long term action plan which lists the key steps that are required in order to improve the soil and increase the amount of carbon.</p> <ul style="list-style-type: none"> ● Cohu might install soil sensors to the fields dedicated to CarbonToSoil - project. Soil sensors provide real time data on the soil's temperature and moisture. After the pilot phase, a farmer can purchase these soil sensors with a discounted price. Soil sensors are particularly suitable for fields which require a lot of watering and vegetables grown under open field. ● Regenerative agriculture builds the soil health and it regenerates unhealthy soils: it improves water retention and plant uptake, improves farm's profitability, reduces costs related to the use of chemical fertilizers & pesticides and revitalizes traditional farming communities while ensuring biodiversity and resilience of ecosystem services and advancement of new farming practices
Potential areas of application	Farming, agriculture
Cost per unit	Freely available application. Farmers in Finland can get subsidy
Environmental impact	Helps reverse the climate changes by supporting regenerative farming
Level of accessibility	Application available from App Store and Google Play

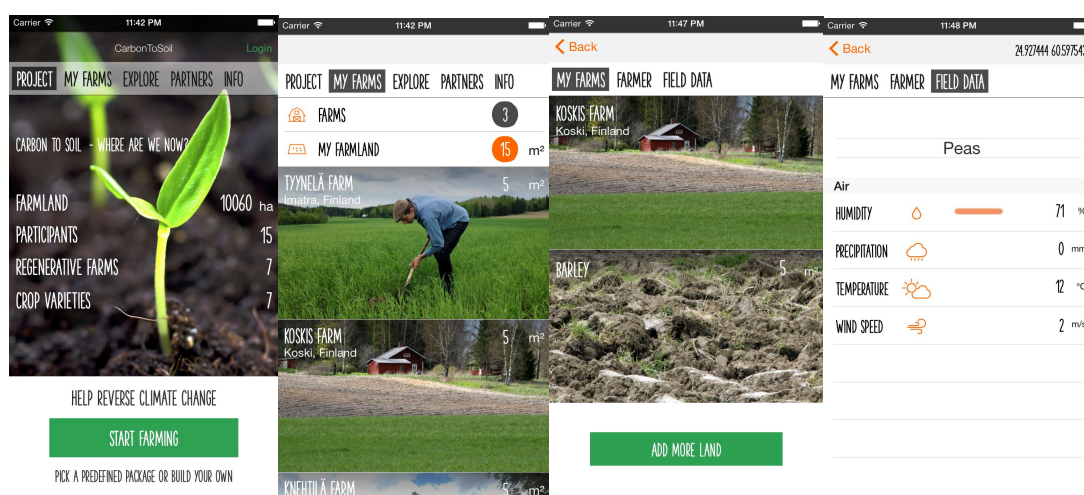


Fig: Different views from the CarbonToSoil application.

Name / ACRONYM	Hyperspectral imaging in UV, VIS, NIR and SWIR regions
Company / R&D / Academia	VTT
Contact person	Anna Rissanen, anna.rissanen@vtt.fi, +358408201972
General information	Hyperspectral imagers based on Fabry-Perot interferometer and image sensor. Design is customizable for different wavelength regions. Research projects related to grass and silage nutrient value measurements, tree identification and hyperspectral imagers in nanosatellites.
Operational status / TRL	7 for grass applications, 9 for hyperspectral imagers.
Country	Finland
Into service	Technology has been available for 10+ years.
Website	https://www.vttresearch.com/services/smart-industry/space-technologies/sensors-imaging-and-data-analysis/optical-microspectrometer https://www.vttresearch.com/media/news/vtt%E2%80%99s-hyperspectral-imaging-technology-ranked-as-one-of-the-top-10 https://www.vttresearch.com/media/news/vtts-hyperspectral-imaging-technology-enables-new-artificial-intelligence-applications-as-a-part-of-consumer-devices
Publications	https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLII-3-W3/165/2017/isprs-archives-XLII-3-W3-165-2017.pdf https://doi.org/10.1117/12.2028972 https://doi.org/10.1117/12.2023299
Extra info	https://www.luke.fi/en/news/drone-project-prepares-ground-new-business-tekes-funding/ https://www.ecsel.eu/projects/afarcloud
Subsector	IoT, Industry 4.0
Area of current application	Healthcare, remote sensing, agriculture
Process steps	1. Define spectral region of interest 2. Design application specific imager, if not readily available 3. Proof of concept testing 4. Application specific spectral analysis software development 5. Commercialization
Benefits	On site and online measurements, instant results, sending samples to laboratory not needed, more accurate data, handheld, low cost, small size and light weight, fast data acquisition.
Potential areas of application	Current and future applications: Vegetation index calculation, Tree species identification, Material identification and composition analysis, Quality control, freshness control, counterfeit detection, nutrient value measurement etc.
Cost per unit	10 - 10 000 euro depending on the application requirements and production volumes
Environmental impact	Improved production, waste reduction, improved quality control, emission reductions based on accurate data driven production etc.
Level of accessibility	Full control / automatic operation depending on the application. Can be programmed to acquire a couple of spectral bands of interest or the full spectrum.

Name / ACRONYM	MEMS based spectral sensors for UV, VIS, NIR and SWIR regions
Company / R&D / Academia	VTT, Spectral Engines
Contact person	Anna Rissanen, anna.rissanen@vtt.fi, +358408201972 sales@spectralengines.com, +358 50 409 0204
General information	MEMS based spectral sensors for different wavelength regions. Cloud based analysis for spectral data. VTT has the technology available for all wavelengths. Spectral engines has commercially available products and application software available for specific wavelengths.
Operational status / TRL	9
Country	Finland
Into service	Technology has been available for 10+ years.
Website	https://www.vttresearch.com/services/smart-industry/space-technologies/sensors-imaging-and-data-analysis/optical-microspectrometer https://www.spectralengines.com/
Publications	https://www.spectralengines.com/solutions/smart-farming/
Extra info	https://www.spectralengines.com/learn-more/
Subsector	IoT, Industry 4.0
Area of current application	Several (e.g., smart farming), new application testing and development fast for ready modules.
Process steps	1. Define spectral region of interest 2. Train cloud based data analysis for the application 3. Commercialization
Benefits	On site and online measurements, instant results, sending samples to laboratory not needed, more accurate data, handheld, low cost, small size and light weight, fast data acquisition.
Potential areas of application	Current and future applications: Quality control, freshness control, counterfeit detection, nutrient value measurement etc.
Cost per unit	10 - 1 000 euro depending on the application requirements and production volumes
Environmental impact	Improved production, waste reduction, improved quality control, emission reductions based on accurate data driven production etc.
Level of accessibility	Full control / automatic operation depending on the application. Can be programmed to acquire a couple of spectral bands of interest or the full spectrum.

Name / ACRONYM	SensLog
Company / R&D / Academia	SensLog
Contact person	senslog@ccss.cz
General information	SensLog is web-based sensor data management system. SensLog is a solution that is suitable for static in-situ monitoring devices as well as for mobile devices with live tracking ability.
Operational status / TRL	Estimated TRL 4
Country	Czech Republic
Into service	N/A
Website	http://www.senslog.org/
Publications	N/A
Extra info	N/A
Subsector	ICT, IoT, Industry 4.0
Area of current application	N/A
Process steps	N/A
Benefits	N/A
Potential areas of application	Throughout the whole chain
Cost per unit	SensLog is Open Source software provided under BSD licence
Environmental impact	N/A
Level of accessibility	Sensors are monitored through system of web-services

Name / ACRONYM	Scienergie
Company / R&D / Academia	Etablissements Mauchamp SAS
Contact person	info@etsmauchamp.com
General information	Specific IT solutions for management and production optimization in wood industry. Available for PC, tablet and mobile phones, the system ranges from forest management to commercial management (trading) to sawmill management (production). Traceability works with variety of identification/marketing solutions (RFID, barcode, numbered plates).
Operational status / TRL	TRL 9
Country	France
Into service	N/A
Website	http://www.etsmauchamp.com/
Publications	N/A
Extra info	N/A
Subsector	ICT, Industry 4.0
Area of current application	Forestry, wood industry
Process steps	N/A
Benefits	Complete solution
Potential areas of application	Forestry, wood industry
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Wuudis
Company / R&D / Academia	Wuudis Solutions Oy (formerly MHG Solutions Oy)
Contact person	info@wuudis.com
General information	Easy-to-use IT solutions for forestry, divided into two services: Wuudis Bioenergy (complete ICT solution for bioenergy production) and Wuudis Business (service package for customer-specific implementation).
Operational status / TRL	TRL 7-9
Country	Finland
Into service	N/A
Website	https://www.wuudis.com/en/
Publications	N/A
Extra info	Initially, Wuudis Bioenergy functions focused on inventory monitoring and managing biomass delivery chains in real-time, but the service have been extended to enable feedstock assessment, origin tracking and terminal management, environmentally sustainable operations and biomass to energy conversion. The concept of the Wuudis Business service is to combine and modify data from different data sources to serve as a knowledge-based product for the customer's needs. The customer product can be an interface, interface service, spatial data, map, plan, report, simulation, document or any combination of these.
Subsector	ICT
Area of current application	Forestry
Process steps	1. Contact 2. Free Webinar Workshop 3. Business case characterization 4. Optional start kit 5. Roll-out of full tailor-made service
Benefits	Efficiency gains, cost savings and environmental benefits to all operators in the value chain, enabling optimization of material and human resources and facilitating operation of more complex business models
Potential areas of application	Supply chains of any biomass
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	The platform can be either integrated into customer's existing information system or accessed through the Wuudis mobile service or the Wuudis Pro browser user interface.

Name / ACRONYM	MooV - Mobilisation and Optimization of Value chains
Company / R&D / Academia	VITO
Contact person	Annelies De Meyer (annelies.demeyer@vito.be) and Ruben Guisson (ruben.guisson@vito.be)
General information	MooV identifies the optimal value chain configuration for any given feedstock while keeping track of the quality changes of the feedstock in space and time. This enables the evaluation of the benefits and bottlenecks in the value chain from supply over logistics to demand.
Operational status / TRL	TRL 8-9: The code is ready to be implemented within cases, projects, etc.
Country	Belgium
Into service	In service since beginning of 2018
Website	Available soon
Publications	Currently applied in different projects, such as IDEA (EU, Interreg NWE), Grassification (EU, Interreg 2Seas), BioWood (BE, FWO)
Extra info	N/A
Subsector	ICT
Area of current application	Currently the main focus is on the bio-based sector, however all kinds of sectors/value chains can be optimized
Process steps	N/A
Benefits	<p>MooV results in wins over the value chain</p> <ul style="list-style-type: none"> - increase of overall resource efficiency - decrease of biomass/material losses - bring down transport costs - decrease greenhouse gas emissions and carbon footprint - increase of the mobilization rate <p>In turn, this leads to direct wins for the respective value chain actors</p> <ul style="list-style-type: none"> - de-risking of strategic decisions (having a long-and-mid-term effect) - improved economic viability - reduced environmental impact - unique insight in the value chain by experimenting with the virtual value chain - identification of opportunities and bottlenecks in the value chain - visually attractive results substantiating decision making
Potential areas of application	Currently the main focus is on the bio-based sector, however all kinds of sectors/value chains can be optimized - MooV is not limited to biomass streams
Cost per unit	To be determined for each case separately
Environmental impact	Include any information on potential environmental impact integrating specified technology within supply chains: Yes, MooV can be used to minimize the CO2 emissions of the whole supply chain leading to reduced environmental impact
Level of accessibility	N/A

Name / ACRONYM	FHPDAT
Company / R&D / Academia	Kooperationsplattform Forst Holz Papier
Contact person	office@forstholzpapier.at
General information	FHPDAT describes the electronic data exchange between the partners in the wood-based supply chain (foresters, logistics, sawmills and industry). In order to achieve maximum efficiency by an increased exchange of information for planning and control of business processes in the forestry and timber industry, FHPDAT provides a transparent means of communication between wood buyers and wood suppliers.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.forstholzpapier.at/index.php/fhpdat
Publications	N/A
Extra info	FHPDAT has dedicated modules for logistics (FHPDATLOG), industry (FHPDATIND), and sawmills (FHPDATSAEGE). Additionally, a new model for billing is currently being developed.
Subsector	ICT
Area of current application	The whole wood-based supply chain
Process steps	N/A
Benefits	Efficient data exchange between stakeholders for better planning and controlling in forestry and wood industry.
Potential areas of application	The whole wood-based supply chain
Cost per unit	The reader is freely downloadable
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	WinforstPro
Company / R&D / Academia	Latschbacher GmbH
Contact person	https://www.latschbacher.com/en/latschbacher_en/contact-person_winfurstpro/
General information	Tailor-made forestry software, wood management, logistics connection, customer administration system (CRM), geographic information system (GIS), settlement statistics.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.latschbacher.com/en/winfurstpro-software_en/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry, Logistics
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry, logistics, administration, cogeneration plants
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixFORST (forest)
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	Wood trading software for supervision and evaluation of timber tradings. Based on the FHPDAT data exchange standard, it provides detailed information on dimension, number of pieces, assortment distribution, costs, revenues, inventories and much more. Digital imaging ensures more transparency, speeds up and facilitates process execution in real time. felixFORST is the optimal tool for all forest owners, forest managers, foresters, timber merchants.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-forst/
Publications	N/A
Extra info	felixFORST is available in two versions BASIS (basic) and PRO. BASIS version can be used free of charge. The required support will be charged separately according to effort. It records all timber deliveries and evaluates them based on the FHP logs received from the timber industry. This ensures a continuous quality control and documents your balance sheets in detail. In addition to the functions of the BASIS version, felixFORST-Pro contains a multitude of analysis and evaluation options. It allows you to analyse your entire timber deliveries with just a few clicks. The system provides you with detailed information on the individual quantities, the assortment distribution, the moulding errors and much more. You can display the results as tables or diagrams. Also, the verification of the billing can be done with a few mouse clicks. Special feature of the Pro version is the log manager, management of concluding letters and service contracts, project management, recording of delivery notes, single master data, overview of quality distribution, summary logs and much more.
Subsector	ICT
Area of current application	Forestry
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixERNTE (harvest)
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	Includes ongoing, digital feedback and mapping of timber harvesting and provisioning in real time. What and how much has been harvested or is available where and when. This provides immediate information about the progress of the processes, as well as the adaptation of subsequent planning and dispositions. Short lead times, lower inventories and less spoilage are the result.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-ernte/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixSÄGE (saw)
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	Software for management and optimization of sawmill operations. felixSÄGE integrates and optimizes the processes from the contract with delivery profile management, wood picking or timber picking, peat management to delivery and acceptance at the factory. The digital capture of all relevant data ensures efficiency and provides an up-to-date overview of processes and status. Automates and documents your timber purchase from contract to billing.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-saegel/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry/sawmills
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry/sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixFRACHT (freight)
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	Tour planning and optimization of all areas of wood logistics. The freight stored with wood data, coordinates, routes, photos and prices are documented with an electronic delivery note and automatically charged. All involved are informed in real time about processes and status.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-fracht/
Publications	N/A
Extra info	felixFRACHT is suitable both for individual carriers with the FrachtGO app and for large logistics companies with the felixLOGISTIKZENTRALE. With the felixLOGISTIKZENTRALE, haulers, forestry companies and the timber industry manage all logistics processes very clearly. It enables the scheduling of several deliveries from loading to takeover in the sawmill. All order data are entered once and made available to all parties digitized and can be transferred to their billing system. felixFRACHT is available in Free, Basic, Business, and Business+ versions.
Subsector	ICT
Area of current application	Forestry, logistics
Process steps	N/A
Benefits	You get all the information about the status of the recorded deliveries in real time and can thus optimize your processes. More rational processes reduce your logistics costs.
Potential areas of application	Forestry, logistics
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixENERGIE (energy)
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	A software tailored to the needs of the materials and energy industry automatically generates the entire order documentation along the information chain involved. The structured data exchange for the efficient control of the transfer system.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-energie/
Publications	N/A
Extra info	The coordinated delivery, digital registration and photo documentation on delivery with self-handling by the supplier, as well as direct software connection to the balance and the weight determination, reduce personnel and administrative costs. The gapless and digital recording in real-time ensures fast and comprehensive evaluations of quantity and quality or generates automated billing.
Subsector	ICT
Area of current application	Forestry, bioenergy
Process steps	N/A
Benefits	Real-time information about the status and quality of deliveries. Reduced costs.
Potential areas of application	Forestry, bioenergy, biorefinery.
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	felixTIMBETER
Company / R&D / Academia	Felix Tools Ges.m.b.H.
Contact person	office@felixsystems.at
General information	Timbeter is a user-friendly tool for measuring timber. Photograph the wood with the app directly from the stack, truck or container. Timbeter calculates the number of tree trunks as well as their volume and diameter.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.felixsystems.at/felixtools/felix-timbeter/
Publications	N/A
Extra info	All measurements are stored in the storage module, from where they can be easily filtered, analysed and downloaded as an Excel file. With each additional measurement you will see how much time you save compared to manual measurements and data entry.
Subsector	ICT
Area of current application	Forest owners, transport companies, sawmills, firewood producers
Process steps	N/A
Benefits	N/A
Potential areas of application	Forest owners, biomass producers, transport companies, sawmills, firewood producers and other end-users.
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Signumat
Company / R&D / Academia	Latschbacher GmbH
Contact person	https://www.latschbacher.com/en/latschbacher_en/contact-person_signumat/
General information	Timber marking and tracking system based on numbering, barcode or RFID chip. Signumat tags are made of high abrasion resistant plastic with consecutive serial numbers, and can be provided with a barcode. This method documents logs in a clean and economical way.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.latschbacher.com/en/signumat-2/
Publications	N/A
Extra info	N/A
Subsector	IoT
Area of current application	Forestry, logistics
Process steps	N/A
Benefits	Timber traceability
Potential areas of application	Forestry and other biomass production, logistics
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	Individual log labels can be read with a reader device.

Name / ACRONYM	GeoMail
Company / R&D / Academia	Forstware Informationssysteme GmbH
Contact person	info@forstware.de
General information	Software solution for logistics and accounting for the wood and forest industry with: <ul style="list-style-type: none"> ● Planning instrument for all timber-trade and forestry concerns ● Software for task management and logistics ● Wood pile tracing from planning up to the plant
Operational status / TRL	TRL 9
Country	Germany
Into service	N/A
Website	http://geomail.biz/english/geomail_produkinfo.html
Publications	N/A
Extra info	Functions: <ul style="list-style-type: none"> ● Geographic functions (there is always a map in the background) ● Inventory and route information ● Driving routes, symbols, marking of working areas ● GPS-navigation ● Communication via email or middleware ● Interfaces to related software systems ● Automated exchange of arbitrary geographic themes between the participants
Subsector	ICT
Area of current application	Forestry, logistics, timber trade
Process steps	N/A
Benefits	<ul style="list-style-type: none"> ● Up-to-date information for all members available at any time ● Improvement of information by digitizing ● Fast overview over all timber piles with quantity, attributes and availability ● Individual customer consulting, support and service ● Improvement of delivery and removal ● Reduction of driving time, prevent timber losses ● Making lists, tables and forms by using integrated or self-made templates ● Specific reporting system assures data consistency and security
Potential areas of application	Forestry, logistics, timber trade
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Energy wood characteristic data calculation
Company / R&D / Academia	Austrian Energy Agency
Contact person	energieholz@energyagency.at
General information	The easy-to-use calculation tool enables quick conversion between standard volume and weight prices. By entering a few factors, the essential characteristics can be quickly determined for different types of energy wood and the assortments compared with each other.
Operational status / TRL	N/A
Country	Austria
Into service	N/A
Website	https://www.klimaaktiv.at/erneuerbare/energieholz/werkzeuge-und-hilfsmittel/kenndatenkalkulation.html
Publications	https://www.klimaaktiv.at/dam/jcr:c65fa134-b319-499a-9137-85022503553a/Manual_Energieholzkenndaten_16_englisch.pdf
Extra info	<p>The energy wood characteristic data calculation offers you the possibility:</p> <ul style="list-style-type: none"> ● to recalculate units: from volume to weight to energy content ● to carry out price comparisons ● compare different wood assortments ● compare wood assortments with different water content ● to calculate the wood consumption and fuel costs for a boiler / heating plant and to choose fuels in any proportion ● compare wood assortments with fossil fuels and enter your own parameters ● to take important characteristics of different tree species and wood assortments from the data sheet <p>The following values are necessary for the calculation:</p> <ul style="list-style-type: none"> ● species ● wood assortment (e.g., logs, wood chips) ● water content ● price <p>Based on specific characteristics, the weight and volume related energy contents and assortment prices are calculated and compared with each other.</p> <p>For biomass plants, it is additionally possible to calculate the annual fuel requirements by weight and volume, to compare different energy wood assortments and to calculate the annual fuel costs.</p>
Subsector	ICT
Area of current application	Bioenergy
Process steps	N/A
Benefits	N/A
Potential areas of application	Bioenergy
Cost per unit	free download
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	ChipCost
Company / R&D / Academia	Timber Technology Institute (TTI)
Contact person	Dr. Raffaele Spinelli, CNR Ivalsa (TTI), info@biomassaforestale.org
General information	Calculation tool for the productivity of chippers and estimation of chipping cost under user-specified working conditions
Operational status / TRL	N/A
Country	Italy
Into service	N/A
Website	http://www.biomassaforestale.org/ivalsa/inglese/inizio_ing.htm
Publications	http://www.biomassaforestale.org/ivalsa/file/IndagineSullaCippaturaintalia.pdf http://www.biomassaforestale.org/ivalsa/file/manualecippatoforestale.pdf
Extra info	<p>The model consists of a <i>Microsoft Excel 5/95, 5/97 and 97</i> workbook that can be downloaded along with instructions file free of charge. The model returns an overall chipping cost once the user has entered specific information on working conditions and costing hypotheses. It allows operators to balance options, according to the user's own operational and economic environment. Users can enter alternative choices and check the economic results of each alternative under the user's own working conditions. Users can supply several inputs to the model, the most important being the average piece size they expect to treat, and the chipper power. Other inputs include equipment purchase prices, depreciation periods, labour rates and other cost assumptions.</p> <p>No specific unit is provided for the currency, so that users may enter the currency of their choice: of course, results will be consistent with the input data – Euros yielding Euros and so on.</p>
Subsector	ICT
Area of current application	Wood chipping
Process steps	N/A
Benefits	N/A
Potential areas of application	Wood chipping
Cost per unit	Free download
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Winlog
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Software for log sorting optimization that offers an all-encompassing control suite for log sorting that guarantees an optimal use of log and merchandising yard. Winlog Sorting Optimization gathers measuring data over the entire production cycle and analyses its efficiency, productivity and recovery based on real time production data.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/winlog/
Publications	N/A
Extra info	Winlog Sorting Optimization automatically sorts logs according to its geometry, quality, species or other customer specific criteria. All measured data is saved in a database and selection criteria are stored and can be recalled at any time. This software relies on measurement data from MiCROTEC's Logeye, iRed, iRas or CT Log scanners and integrates seamlessly with existing software. Margins for improving recovery are clearly identified by Winlog Sorting Optimization ensuring a transparent and information-based decision-making.
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	Optimized log sorting, control of the log and merchandising yard as it: <ul style="list-style-type: none"> ● Provides all necessary information for the log sorting line ● Gathers all log information and creates reports by date, supplier, log qualities, etc. ● Automates and streamlines production processes and log procurement ● Creates database of log information (reports, tracking) ● Exchanges information through open protocols and interfaces
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Interopt
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Bucking optimization software for logs by dimension, quality or highest value cutting pattern. It calculates the optimum merchandising solution according to dimension, curvature, taper and quality information and optimizes bucking according to real time priorities. The solutions are optimised in various areas according to the overall resale value of the recovered lumber.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/interopt/
Publications	N/A
Extra info	Interopt Bucking Optimization controls the bucking saw and the sorting line. It relies on measuring data delivered by MiCROTEC's Logeye 300 Multi-Sensor Quality Scanner or CT Log Computed Tomography Scanner.
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> • Optimizes bucking based on external shape and internal log quality information measured by computed tomography • Real time data processing and bucking optimization • Enables individual customer quality requirements for log bucking • Is fine-tuned to your plant-specific configuration • Integrates seamlessly with all MiCROTEC measuring systems and solutions
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Variosort
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Variosort Lumber Sorter supervises the fully automated sorting and packaging, bundling and wrapping of lumber. It works with all mechanical systems such as horizontal and vertical sorters, green or dry buffers, etc. Variosort Lumber Sorter also manages trimming.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/variosort/
Publications	N/A
Extra info	<p>This application relies on measurement data of the Goldeneye Multi-Sensor Quality Scanner, Wanescan Edge, Viscan Strength Grader, M3 Scan Moisture Meter, Optiside Cup Scanner, Variosort Lumber Scanner or other proprietary lumber scanners and integrates with existing software.</p> <p>Variosort features:</p> <ul style="list-style-type: none"> • Controls sorting and packaging at high speeds • Operates with all common mechanical systems • Allows quick and efficient sort changes • Optimizes use of boxes through dynamic allocation • Controls trimming, bundling and packaging • Visualizes ongoing operations status and shows outages • Reduces wear with intelligent box feeder valve control <p>Variosort sorting criteria</p> <ul style="list-style-type: none"> • Geometry – length, width and thickness • Quality / resale value • Strength classes • Moisture content
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	Variosort Lumber Sorter features infrared scanners, distance sensors, laser 3D triangulation or Multi- Sensor cameras. The Variosort Lumber Scanner seamlessly integrates into existing plants and can be customized to meet different quality and accuracy requirements.
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Goldeneye Plus Hardwood Grader
Company / R&D / Academia	MICROTEC
Contact person	info@microtec.eu
General information	Goldeneye Plus is a solution for automated machine grading of hardwood lumber. The software reliably grades hardwood lumber based on internationally recognized NHLA grading standards. Furthermore, Goldeneye Plus automatically manages the sorting process into different NHLA grades.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/hardwood-grader/
Publications	N/A
Extra info	The specialized software in combination with the Goldeneye 600 or 900 Multi-Sensor Quality Scanner scans in linear or transversal feed direction and was specially developed for grading rough, kiln dried lumber. Goldeneye Plus hardwood grader features an innovative low-power X-ray, line and dot lasers and in-house developed cameras and sensors. It is designed to scan hardwood lumber at speeds of up to 1,000 linear feet per minute and up to 200 boards per minute in transverse feeding. Goldeneye scanners are capable of scanning random width boards up to maximum NHLA thickness and length sizes.
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> ● Optimization of staff and reduction of costs ● 24/7 pure reliability without any fatigue ● Increased accuracy and capacity ● Scalable solutions and costing certainty for your increasing business ● Elimination of labour-intensive, costly grading and regrading
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Maxicut
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Maxicut Best Cut Solution provides a breakdown optimization. It considers geometry, quality and resale value of final products as well as customer specific product quality requirements while evaluating the optimum cutting pattern of logs. The software simulates and calculates the best possible yield and lumber recovery that can be obtained by combining different final products. Maxicut Best Cut Solution determines the saw blades positions of the cutting machines.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/maxicut/
Publications	N/A
Extra info	<p>Maxicut features</p> <ul style="list-style-type: none"> • Cutting pattern optimization based on final product quality and value • Saw infeed control: Integrates with all breakdown machinery such as profiling lines or band saws • Considers cutting pattern solutions in various areas within the log • Masters all breakdown techniques including single or multiple prism patterns, live cuts or straight and curve sawing • Intuitive user friendly user interface • Prioritizes production based on your orders or customer specific lumber dimensional and quality parameters <p>Maxicut Best Cut Solution integrates seamlessly with other applications from Microtec such as Interopt Bucking Optimization featuring cutting pattern solutions in various areas within the log or Winlog Sorting Optimization featuring log sorting by cutting pattern.</p>
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	Maxicut's sharp and accurate cutting pattern optimization you can significantly increase the yield of your sawmill.
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Virtual Cut
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	<p>Virtual Cut Breakdown Simulation is a tool combining Microtec's Maxicut Best Cut Solution and TimberTec's Timber Commerce Cutting Pattern Calculation in order to produce logs virtually with their possible cutting patterns when they are still in the bin.</p> <p>Virtual Cut is able to determine the best value cutting pattern for each pre-sorted log pile by virtually simulating all possible cutting patterns for every log in the batch considering real 3D data. Virtual Cut ensures an optimum work preparation and breakdown value maximization.</p> <p>The 3D log data for the cutting pattern calculation are provided by a 3D scanner installed at the log yard, measuring the log contour. In the course of breakdown preparation, TimberTec selects the logs to be cut and delivers a set of possible cutting patterns to Maxicut. Maxicut Best Cut Solution simulates and returns the optimum cutting pattern, which maximizes the resale value of all the products to be generated.</p>
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/virtualcut/
Publications	N/A
Extra info	<p>Virtual Cut Breakdown Simulation relies on measuring data from a 3D scanner installed at the log yard such as Logeye 300 Multi-Sensor Quality Scanner. These data are saved and sent to Maxicut Best Cut Solution by TimberTec's Cutting Pattern Calculation. Maxicut simulates the breakdown log by log, choosing the most valuable cutting pattern out of a user defined list. The optimization is personalized to each sawmill layout and equipment taking into account only cutting patterns that can be actually realized, thus providing highly reliable yield results.</p> <p>Combined with Microtec's CT Log Computed Tomography or X-ray Quality Scanners, Virtual Cut also provides an optimization in the final yield according to the internal qualities of the logs.</p>
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> • Selects the best value cutting pattern for each bin by virtually simulating all possible cutting patterns for every log in the batch considering real 3D data • Maximizes the resale value of all products which can be cut from the log • Ensures an optimum work preparation and breakdown value maximization
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Mill Manager
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Microtec Mill Manager is software suite for mill wide control and reporting, displaying real-time production information. A production monitoring tool that offers access to up-to-the-minute reports and data for all your scanning and optimization systems, and provides an instant analysis of all machine centres in your mill (remotely interacts with dumpers, sorting lines, saw infeed, secondary breakdown, cross-cut systems, palleting units, forklift displays and barcode scanners).
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/millmanager/
Publications	N/A
Extra info	All logs coming into the sawmill are consolidated in a central database, they are scanned, graded and sorted. All traceability information is entered and shown in production inventory. New production orders are inserted directly into the system, keeping track of what has been processed, re-manufactured and packed. From purchase orders to sales orders, Mill Manager can optimize overall mill processes and increase the productivity of its operations. It helps to eliminate waste and improve efficiency by increased recovery through better understanding of input material, lower production costs by capturing key performance indicators, and lower transport costs from better management of orders.
Subsector	ICT
Area of current application	Sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> • Deep insight into all aspects of your mill in real time • Shift reports, monitoring of production, recovery and other key operating statistics • Optimization of feed and production flow of processing lines to avoid production gaps • Prediction and planning around potential maintenance issues to avoid downtimes • Automated generation of customized reports for all team members, telling them exactly what they need to know at just the right time • In-depth comprehensive interfaces with ERP solutions (bi-directional), PLC Control and other existing systems currently running in the plant • Flexible and customizable, easily integrated at any point within processing plant • Full traceability of wood resources at all stages of production • Multi-mill capability • Web based software accessible from anywhere
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Smart Mill
Company / R&D / Academia	MiCROTEC
Contact person	info@microtec.eu
General information	Smart Mill is a complete solution, providing illumination, network, 3D imaging, and optimization for the Sawmill 4.0. Sawmill owners know their sawmill operations – hour by hour, day by day. Qualified data such as log yard inventory, dimension and quality of every log in the log yard or machinery movements and more are readily available. Complete with Mill Manager, the Smart Mill continuously optimizes the Sawmill 4.0 operations.
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://microtec.eu/en/catalogue/products/smartmill/
Publications	N/A
Extra info	<p>Smart Mill features high mast lighting poles that include LED lights, WiFi transmitters and stereoscopic cameras interconnected with an all-encompassing Mill Manager software that collects all scanning and optimization data.</p> <p>The availability of a global WiFi network is the backbone of an integrated and interconnected manufacturing site and a necessary prerequisite for the sawmill 4.0. The WiFi network connects all machinery and operators and ensures smooth operations. It allows you to remotely interact with dumpers, forklift displays and log infeed units.</p> <p>Stereoscopic cameras mounted on the light poles capture 3D images of the monitored area, for example log piles at your merchandising yard, saw dust stock, lumber packets and more can be captured by the system to ensure a constant inventory control. High efficiency LED lightings increases workplace safety, reduces lighting costs and improves illumination throughout the sawmill. The lighting is also optimizing the integrated camera operations.</p>
Subsector	Industry 4.0
Area of current application	Sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> • 3D image of the sawmill • Integrated manufacturing 4.0 through seamless WiFi interconnectivity • High efficiency LED illumination for improved lightning • Optimized sawmill operations and work preparation • 100% control of your sawmill (log yard, machinery, inventory)
Potential areas of application	Sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	WinGIS
Company / R&D / Academia	PROGIS Software GmbH
Contact person	office@progis.com
General information	Spatial engine, very fast and powerful object-oriented GIS with its own development environment, developed with focus on agriculture, forestry, and environment and natural risk-management
Operational status / TRL	TRL 7-9
Country	Austria
Into service	N/A
Website	http://www.progis.com/
Publications	N/A
Extra info	WinGIS engine is embedded in various management tools (DokuPlant, ForestOffice), modules (sensor integration, animals), and services offered by ProGIS.
Subsector	ICT
Area of current application	Agriculture, forestry, logistics, environment and natural risk-management
Process steps	N/A
Benefits	<p><i>Agriculture:</i> farmers or group of farmers or entire countries are managed, with GIS and maps, farm-/forest-management, logistics, chain integration, precision farming, land consolidation etc.</p> <p><i>Forestry:</i> with GIS and forest maps based on ortho-images, forest inventory system based on Relaskop-measurements and automatic stocking-/growth-calculation and the entire forest management.</p> <p><i>Logistics:</i> integrates the entire chain from farmers, machines and drivers, suppliers and buyers, service providers and even banks or insurance companies if wanted to optimize all the processes with a trust center® in background.</p> <p><i>Environment risk management:</i> farmers and foresters influence the environment and natural risks. Optimized model – planned and implemented with WinGIS and EnvirOffice – will create new services.</p>
Potential areas of application	Agriculture, forestry, logistics, environment and natural risk-management
Cost per unit	N/A
Environmental impact	Helps in monitoring / assessing the influence of a certain activity on environment, and managing the related risks
Level of accessibility	N/A

Name / ACRONYM	Holz V6
Company / R&D / Academia	Haugensteiner EDV
Contact person	Johann Haugensteiner, j.haugensteiner@haugensteiner.at http://www.haugensteiner.at/kontakt/kontaktformular/index.php
General information	Business management software tool for wood traders and sawmills
Operational status / TRL	TRL 9
Country	Austria
Into service	2010
Website	http://www.haugensteiner.at/index.html
Publications	http://www.haugensteiner.at/presse/index.html
Extra info	N/A
Subsector	ICT
Area of current application	Wood trade and sawmills
Process steps	N/A
Benefits	<ul style="list-style-type: none"> ● integrated solution ● maximum transparency ● meaningful evaluations ● controlled documents ● high-performance work ● mobile data collection ● mobile printing solution ● FHP formats
Potential areas of application	Wood trade and sawmills
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

6.3. Online platforms and databases

Name / ACRONYM	Scottish Bioresource Mapping Tool
Company / R&D / Academia	IBioIC
Contact person	info@ibioic.com
General information	The Scottish Bioresource Mapping Tool is a pioneering approach to mapping bioresource arising providing potential investors in the bioeconomy and circular economy uniquely detailed information on the 27 million tonnes of bioresources arising every year in Scotland, which have been analysed so far.
Operational status / TRL	Further updates expected to increase user friendliness and range of feedstocks
Country	United Kingdom
Into service	2017
Website	http://www.ibioic.com/what_we_do/scottish_bioresource_mapping_tool/d1142/
Publications	https://www.zerowastescotland.org.uk/sites/default/files/Biorefining%20Potential%20for%20Scotland%20Final%20report.pdf
Extra info	N/A
Subsector	ICT
Area of current application	Biomass supply chain modelling
Process steps	N/A
Benefits	Knowledge of available biomass with its type and geographic breakdown
Potential areas of application	Planning new supply chains or biorefinery investments
Cost per unit	N/A
Environmental impact	Efficient utilisation of biomass
Level of accessibility	Reports of specific data requests can be generated by IBioIC

Name / ACRONYM	Holzauktionen (wood auction platform)
Company / R&D / Academia	Österreichische Bundesforste AG
Contact person	holzauktionen@bundesforste.at
General information	Online trading platform for wood run by Austrian Federal Forests
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	https://www.holzauktionen.at/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry: wood providers, traders, and end-users
Process steps	<ol style="list-style-type: none"> 1. Register online. 2. Complete, sign and send back the official form 3. Once it's processed you will receive an e-mail 4. Log in 5. Enjoy buying or selling
Benefits	N/A
Potential areas of application	Forestry: wood providers, traders, and end-users
Cost per unit	free
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Cerco/Offro
Company / R&D / Academia	Legno Trentino
Contact person	progetto.legno@tn.camcom.it
General information	Online trading platform for selling round wood and other wood products
Operational status / TRL	TRL 9
Country	Italy
Into service	N/A
Website	https://www.legnotrentino.it/it/cercooffro/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry: wood providers, traders, and end-users
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry: wood providers, traders, and end-users
Cost per unit	free
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Eschlböck Woodchip Exchange
Company / R&D / Academia	Eschlböck Maschinenfabrik GmbH
Contact person	office@eschlboeck.at
General information	Online trading platform for wood chips.
Operational status / TRL	TRL 9
Country	Austria
Into service	N/A
Website	http://www.eschlboeck.at/en/boerse
Publications	N/A
Extra info	Offers can be searched with various criteria, such as distance, quantity, origin of wood chips (from recycled wood, bark/stem_wood/whole_trees from forest/agriculture, wood from sawmill with/without bark, etc.), wood chips class (small/medium/large), moisture, wood kind (hard/soft).
Subsector	ICT
Area of current application	Wood chips trade
Process steps	Selling requires registration
Benefits	N/A
Potential areas of application	Forestry and timber trade
Cost per unit	free service
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Giełda biomasy
Company / R&D / Academia	BIOMA Odnawialne Źródła Energii
Contact person	kontakt@ebiomasa.pl
General information	Giełda biomasy is a biomass marketplace where you can place bids for purchase or sale of broadly understood biomass as well as products and services in the renewable energy sector.
Operational status / TRL	TRL 9
Country	Poland
Into service	N/A
Website	http://www.ebiomasa.pl/gielda-biomasy
Publications	N/A
Extra info	In addition to biomass marketplace, the platform includes: <ul style="list-style-type: none"> • catalogue of companies operating in renewable energy field including biomass producers and traders as well as machinery and service providers. • news on bioenergy, renewable energy sources and forestry • discussion forum on related topics.
Subsector	ICT
Area of current application	Mainly wood-based biomass trading
Process steps	Registration required
Benefits	Complete source of information on biomass availability, and technologies, services and stakeholders in renewable energy market.
Potential areas of application	All sorts of biomass
Cost per unit	Free
Environmental impact	Promoting the usage of biomass as well as other renewable energy solutions contributes to reduced reliance on fossil fuels and overall carbon footprint.
Level of accessibility	N/A

Name / ACRONYM	Big DATABIO Platform
Company / R&D / Academia	INTRASOFT INTERNATIONAL SA (project coordinator)
Contact person	Project Coordinator: Dr. Athanasios Poulakidas, Athanasios.Poulakidas@intrasoft-intl.com see also: https://www.databio.eu/en/contacts/
General information	A big data platform being developed within “Data-Driven Bioeconomy (DataBio)” project (2017-2020) on top of the existing partners’ infrastructure and solutions. The main goal of the DataBio project is to show the benefits of Big Data technologies in the raw material production from agriculture, forestry and fishery/aquaculture for the bioeconomy industry to produce food, energy and biomaterials responsibly and sustainably.
Operational status / TRL	TRL 2
Country	The DataBio consortium includes partners from 17 countries (in alphabetic order): Belgium (coordinator), Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Romania, Spain, Switzerland, United Kingdom.
Into service	2020
Website	https://www.databio.eu/en/
Publications	https://www.databio.eu/en/publications/
Extra info	The DataBio project focuses on the production of best possible raw materials from agriculture, forestry and fishery for the bioeconomy industry to produce food, energy and biomaterials taking into account responsibility and sustainability. In order to meet the above objectives, DataBio is controlling and putting to use the innovative ICTs and information flows centred mostly around the use of proximal and remote sensors, in order to provide a streamlined Big Data Infrastructure for data discovery, retrieval, processing and visualizing, in support to decisions in bioeconomy business operations.
Subsector	ICT
Area of current application	Different biomass production (agriculture, forestry and fishery)
Process steps	N/A
Benefits	N/A
Potential areas of application	Any kind of biomass production
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Ositrade
Company / R&D / Academia	Ositrade au LAB'O
Contact person	https://www.ositrade.fr/en/contact/
General information	<p>Ositrade is an online marketplace for professional users. Permissioned access with payment of a subscription plus a per m-tonne transaction fee charged to the buyer.</p> <p>From farmers to industrials, collectors and traders to exporters, anonymized orders (ask) and offers (bids) gives market depth in time and geographies of any Ag-commodity. Standard qualities can be adjusted to specific lots, Organic or conventional and MATIF premium type contracting as well.</p>
Operational status / TRL	TRL 7-9
Country	France
Into service	2018
Website	https://www.ositrade.fr/en/
Publications	https://www.foodnavigator.com/article/2018/06/18/blockchain-agri-marketplace-ositrade-launches
Extra info	<p>Blockchain guaranties ask & bids are binding, and secures transaction terms as soon as they are booked. They can be downloaded and printed with a few clicks.</p> <p>Because each trade is securely recorded on the blockchain, the system can liquidate any chained contract automatically. It identifies the lowest price and informs each party of the price difference to be invoiced according to the Incograin rule.</p> <p>A special organic market is included in the App using the same rules.</p> <p>Each trade is notified to you and contract terms can be exported or printed.</p>
Subsector	ICT
Area of current application	Agrimarket
Process steps	<ol style="list-style-type: none"> 1. Ositrade validates each application for registration on the platform and grants access. 2. Operators create their ask and bids, look up the market with filters to help them, accept or negotiate propositions – with a chat box, receive notifications. 3. Counterparts can connect immutably documents requested for the execution, this provides traceability.
Benefits	<p>Security, differentiation, transparency, traceability.</p> <p>By securely connecting all links of a supply chain without a trusted third party, Ositrade redistributes added value and responsibilities to the players and simplifies admin processes.</p>
Potential areas of application	Agrimarket
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	Copernicus
Company / R&D / Academia	The Programme is coordinated and managed by the European Commission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.
Contact person	support@copernicus.eu
General information	Copernicus is the European Union's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It offers information services based on satellite Earth Observation and in situ (non-space) data.
Operational status / TRL	TRL 9
Country	Luxembourg
Into service	2012 (Land), other sections mainly since 2015
Website	https://www.copernicus.eu/en http://data.copernicus.eu/data-access.html
Publications	https://www.copernicus.eu/en/library/library
Extra info	Copernicus builds on a constellations of satellites making an impressive number of daily observations, as well as on a global network of thousands of land-, air- and marine-based sensors to create the most detailed pictures of Earth. The technological evolution, especially in terms of availability and accessibility, has made Copernicus the largest space data provider in the world, currently producing 12 terabytes per day. The vast majority of data and information delivered by the Copernicus Space infrastructure and the Copernicus services are made available and accessible to any citizen and any organisation around the world on a free, full and open access basis. You can access Copernicus Data and Information Services through the DIAS or the Conventional Data Hubs.
Subsector	ICT
Area of current application	Forecasting weather; tracking biodiversity and wildlife trends; measuring land-use change (such as deforestation); monitoring and responding to natural disasters, including fires, floods, earthquakes, landslides, land subsidence and tsunamis; managing natural resources, such as energy, freshwater and agriculture; addressing emerging diseases and other health risks; predicting, adapting to and mitigating climate change.
Process steps	1. online registration 2. subscription or ordering 3. data download
Benefits	N/A
Potential areas of application	With growing amount, quality and accuracy, new application emerge.
Cost per unit	The information services are freely and openly accessible to its users.
Environmental impact	Monitoring the climate changes, providing data and analyses to warn about geohazards and aid in mitigating the negative effects of civilization on environment.
Level of accessibility	N/A

Name / ACRONYM	VITO Earth Observation
Company / R&D / Academia	VITO
Contact person	contact through website
General information	Distribution portal for satellite image and airborne spectroscopy image data. Both free and commercial data sets are available.
Operational status / TRL	TRL 9
Country	Belgium
Into service	N/A
Website	https://www.vito-eodata.be/PDF/portal/Application.html#Home
Publications	N/A
Extra info	https://www.vito-eodata.be/PDF/image/faq_help/Faq.html https://www.youtube.com/watch?v=4-qPq6tX8pE
Subsector	ICT
Area of current application	Depending on user needs
Process steps	Registrations required
Benefits	N/A
Potential areas of application	Depending on user needs
Cost per unit	Both free and restricted access data sets available
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	BorzaLesia
Company / R&D / Academia	Si.natura d.o.o. / Zavod Big
Contact person	info@zavodbig.si
General information	Wood trading portal. Online platform selling and purchasing of logs, sawn timber, semi-finished products and services.
Operational status / TRL	TRL 9
Country	Slovenia
Into service	N/A
Website	http://www.borzalesa.com/
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry and timber trade
Process steps	Registration required
Benefits	N/A
Potential areas of application	Forestry and timber trade
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	e-drewno
Company / R&D / Academia	PGL Lasy Państwowe (Polish State Forests)
Contact person	https://www.e-drewno.pl/stock/?product=stock&module=auctions&action=about&id=175090000000006
General information	e-drewno system was created in order to enable customers to take part in a wood sale auction in a forest district without necessity of physical attendance.
Operational status / TRL	TRL 9
Country	Poland
Into service	N/A
Website	https://www.e-drewno.pl/stock/?lang=en
Publications	N/A
Extra info	N/A
Subsector	ICT
Area of current application	Forestry
Process steps	<p>After registration in the system the customer gets individual access to the system, enabling participation in the auction.</p> <p>In order to register in the system, all the fields of a registration form have to be filled in. The user gives a unique login and password. The login can be a combination of letters and digits (it must have six characters at least) and does not have to include company name or any other element that could be used for identification of the user. During the registration all the users are expected to give the parent forest district name. For practical reasons it is recommended to give the forest district which is located closest to the place of residence / running business activity.</p> <p>After filling in the registration form for individual customers or during the first log in for the companies, the customer will receive a message sent to the e-mail address given in the form, including all information on documents which have to be sent to the parent forest district before the system account can be activated.</p>
Benefits	<ul style="list-style-type: none"> ● Buying directly from the producer via open auction assures the best possible market price for the wood. ● Only sustainably grown and legally cut wood from official state representative.
Potential areas of application	Forestry
Cost per unit	N/A
Environmental impact	PGL Lasy Państwowe is a state owned company taking care of forests' biodiversity, and protects them from many threats: natural disasters, pest infestations, tree diseases, fires, pollution, and from the consequences of poaching and vandalism. PGL Lasy Państwowe also ensures that the forest management is carried out in accordance with the principles of sustainable development, taking into account all the functions that forests fulfil.
Level of accessibility	N/A

Name / ACRONYM	Agri MarketPlace
Company / R&D / Academia	Agri MarketPlace
Contact person	info@agrimp.com
General information	B2B marketplace between farmers and end users (industry/retail,) created to raise prospects to farmers and value to all food supply chain. The current selection of commodities include: rice, wheat, maize, barley, triticale, and almonds.
Operational status / TRL	TRL 7-9
Country	Portugal
Into service	N/A
Website	https://agrimp.com/
Publications	N/A
Extra info	The platform is available in four languages: English, Portuguese, Spanish, and French. It offers following services: <ul style="list-style-type: none"> • Digital Trading Platform • Sales Contracts Agreements • Logistics & Transportation • Quality Insurance of Products
Subsector	ICT
Area of current application	Agrimarket
Process steps	N/A
Benefits	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
Potential areas of application	Agrimarket, markets and supply chains of any biomass
Cost per unit	N/A
Environmental impact	N/A
Level of accessibility	N/A



Fig: Pictogram presenting the span of Agri MarketPlace's business model.

Name / ACRONYM	EUROSTAT portal for statistics database
Company / R&D / Academia	EUROSTAT (European Commission)
Contact person	https://ec.europa.eu/eurostat/help/support
General information	The EUROSTAT is pan-European platform providing information database and statistics, covering multiple aspects of environment, life and economy. The database is divide into themes. From the biomass supply chains' point of view, the most important sections include agriculture, fishery, forestry, transport, and waste. The EUROSTAT is a broad and reliable source of data providing insights on many aspects of biomass availability, production, trade and utilization.
Operational status / TRL	TRL 9
Country	Luxembourg
Into service	N/A
Website	https://ec.europa.eu/eurostat/data/statistics-a-z/abc
Publications	https://ec.europa.eu/eurostat/web/agriculture/publications https://ec.europa.eu/eurostat/web/fisheries/publications https://ec.europa.eu/eurostat/web/forestry/publications https://ec.europa.eu/eurostat/web/transport/publications https://ec.europa.eu/eurostat/web/waste/publications
Extra info	The database of Eurostat contains always the latest version of the datasets meaning that there is no versioning on the data. Datasets are updated twice a day, at 11:00 and at 23:00, in case new data is available or because of structural change.
Subsector	ICT
Area of current application	Agriculture, fishery, forestry, transport, and waste among many others.
Process steps	<p>Aggregated information is available for direct download or browsing online. The access to microdata is restricted and access to it is granted for scientific purposes only. Applying for access to microdata consists of two steps:</p> <p><i>Step 1:</i> Apply to have your research organisation recognised as a research entity. You only need to do this once, no matter how many access requests you make subsequently (the procedure takes around 4 weeks).</p> <p><i>Step 2:</i> Apply for access to microdata. Once we have recognised your organisation as a research entity, you can apply for access by submitting a research proposal (the procedure takes around 8-10 weeks).</p>
Benefits	Complete, reliable, and periodically updated source of data.
Potential areas of application	Agriculture, fishery, forestry, transport, and waste among many others.
Cost per unit	free
Environmental impact	N/A
Level of accessibility	N/A

Name / ACRONYM	BALTPOOL Biomass Exchange
Company / R&D / Academia	BALTPOOL UAB
Contact person	https://www.baltpool.eu/en/contacts/
General information	The Biomass Exchange is an on-line trading venue operating according to the set rules and providing buyers and sellers with an opportunity to finalize contracts electronically in the Biomass Product Exchange. The Biomass Exchange operates as the central venue in which market participants – sellers (suppliers of biomass) and buyers (normally heat production companies) – meet anonymously. By means of the trading system of the exchange, the participants can quickly and easily sell their products and purchase the required quantity of biomass.
Operational status / TRL	TRL 9
Country	Lithuania
Into service	2012
Website	https://e.baltpool.eu/biomass/?lang=en
Publications	https://energypost.eu/trading-biomass-like-oil-lithuania-shows-how-it-can-be-done/
Extra info	https://www.baltpool.eu/en/about-exchange/ https://www.baltpool.eu/en/how-to-trade/
Subsector	ICT
Area of current application	Biomass trading, bioenergy
Process steps	<ol style="list-style-type: none"> <i>Membership application</i> To become a member at BALTPOOL, an applicant shall submit Member Registration form. <i>Risk assessment and decision regarding application</i> BALTPOOL will conduct an assessment of risk and received documents and decide regarding your application. If there are any additional information required – one of team members will promptly contact you. <i>Signing of participant agreement</i> After the application is approved, we will send you a signed participant agreement. Now you are ready to start trading.
Benefits	<p>Transparent competition:</p> <ul style="list-style-type: none"> all parties are provided with equal conditions to become participants of the exchange; open negotiations take place in the electronic environment; anonymity of participants is ensured; contract prices are published. <p>Reliability:</p> <ul style="list-style-type: none"> availability of a system for securing fulfilment of obligations in compliance with the current market conditions; grouping of participants by the degree of their financial reliability and production capacity. <p>A clear system:</p> <ul style="list-style-type: none"> a simple and clear process for placing orders and finalising contracts; trade in standardised products; a clear process for establishing biomass quantities and quality. <p>Effectiveness:</p> <ul style="list-style-type: none"> easy and quick finalisation of contracts in the electronic system; centralised collection and signing of documents; the Biomass Exchange takes care of the required documentation.

	<p>Best price:</p> <ul style="list-style-type: none"> ● buyers and sellers are grouped based on the best price offered; ● possibility to buy from several sellers who submitted the best offers; ● sellers submit offers simultaneously to all buyers in the selected transportation distance interval; ● competition ensures the best price of biomass.
Potential areas of application	Trading of any biomass for any use
Cost per unit	N/A
Environmental impact	Promotes the use of biomass for energy production, thus reducing the dependency on fossil fuels
Level of accessibility	N/A

Name / ACRONYM	Online catalogue of forestry companies and wood fuel producers
Company / R&D / Academia	Slovenian Forestry Institute
Contact person	Nike Krajnc, nike.krajnc@gozdis.si
General information	Online catalogue of forestry companies and wood fuel producers with over 2100 contact details of forestry companies and wood fuel producers from 9 EU countries (Austria, Croatia, Germany, Greece, Ireland, Italy, Romania, Slovenia and Spain).
Operational status / TRL	TRL 7
Country	Slovenia
Into service	2014
Website	http://www.biomassstradecentre2.eu/wood-biomass-production/service-providers/ http://www.gozdis.si/raziskovalna-dejavnost/proizvajalci-lesnih-goriv/
Publications	http://www.biomassstradecentre2.eu/available-literature/
Extra info	The catalogue is the outcome of the “Development of biomass trade and logistics centres for sustainable mobilization of local wood biomass resources – BiomassTradeCentrell ” project (co-funded by The Intelligent Energy Europe Programme of the European Union). The project aimed at increasing the production and the use of energy from wood biomass by organizing motivation events and presenting clear, integrated, and market-oriented information to potential investors: farmers and forest owners, forest entrepreneurs, wood energy contractors and other stakeholders regarding business opportunities to produce and sell energy products and services.
Subsector	ICT
Area of current application	Forestry
Process steps	N/A
Benefits	N/A
Potential areas of application	Forestry
Cost per unit	free
Environmental impact	N/A
Level of accessibility	N/A

7. Conclusions

The mapping of the ICT, IoT and Industry 4.0 technologies and solutions has been divided into two parts - regional and pan-European.

The regional part concerns the regions in which the ICT-BIOCHAIN project will establish Digital Innovation Hubs, i.e., SE Ireland and Andalusia, Spain. In this part, the process involved questionnaires and phone calls with local stakeholders as well as analysis of the projects conducted within those regions. 16 regional case study examples of ICT technology applied to biomass supply chains were identified in the regional scoping. 8 of these were in the Andalusia region, and 8 were in the Irish region. The technology examples of Andalusia are evenly distributed among the subsectors of ICT, IoT, and Industry 4.0 with TRL levels varying from TRL 4 to TRL 9. The agriculture/farming/agrifood domain is dominant, and the solutions currently applied in municipal field also have the potential for integration within biomass supply chains. The majority of the Irish examples were in the domain of ICT with TRL levels varying between TRL 4 and TRL 9. The predominant feedstock of current application is forest-based biomass (lignocellulose) with other areas of application including cereal residues (straw), municipal solid waste and sewage sludge also considered with potential for the technologies to be applied to a variety of biomass supply chains. Technologies include a sensor kit to monitor fresh material in transport to improve environmental conditions and reduce waste, various data models to support decision making on efficient supply chains for bioeconomy and use of modelling for rapid analysis of bioresource characteristics.

In the pan-European part, the process involved screening of European projects related to bioeconomy, literature survey, internet searches as well as direct contacts with stakeholders. 60 technologies, tools, and solutions were identified for the pan-European section, with TRL 9 dominating the distribution. Many of the solutions are commercially offered by multiple companies, which indicates that some of the potential business opportunities have already been recognized. Apparently, the market size and maturity is a crucial factor. Majority of the applications are within the forestry and wood industry, which is still a dominant biomass market. However, with growth of sustainable bioeconomy supported by EU, and thus increasing diversity of available biomass, more and more technologies are being used in other markets or supply chains. Many solutions proven useful within the wood industry (such as conditions monitoring, traceability, trading platforms, and supply management tools) could be extended or adapted to other types of biomass. For instance, smart farming becomes a rapidly growing sector.

The following charts visualize the statistical summary of the captured state of the art in ICT, IoT, and Industry 4.0 solutions.

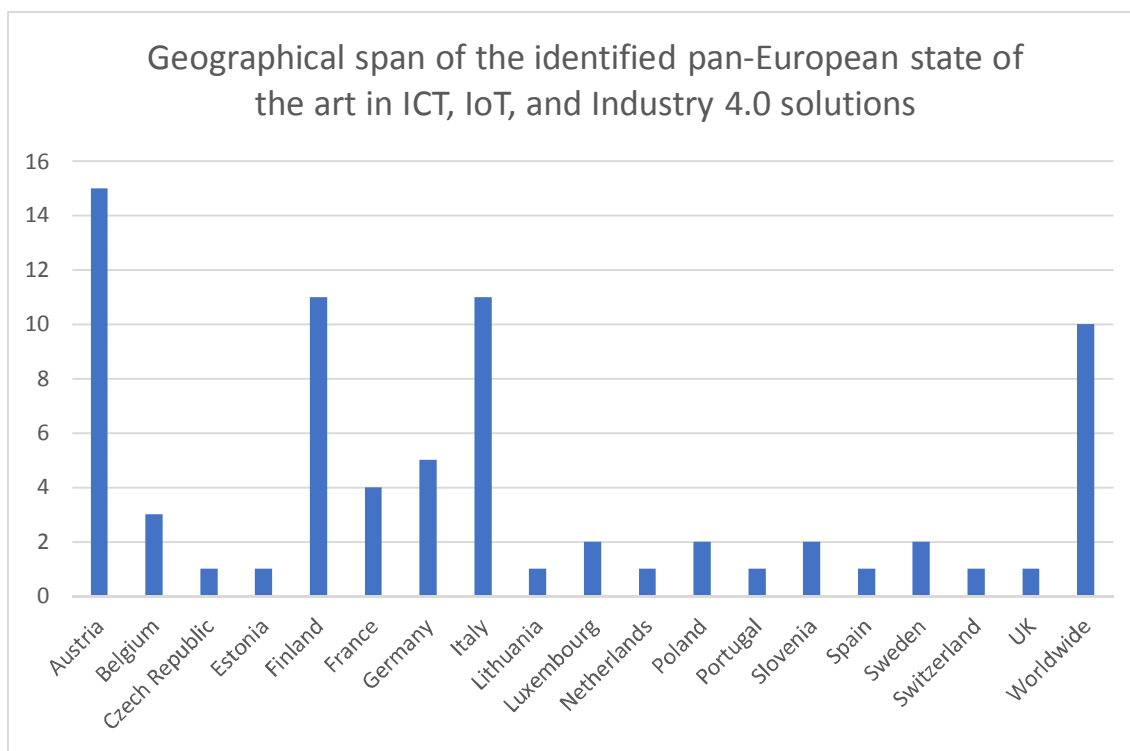


Fig: Geographical distribution of the pan-European state of the art in ICT, IoT and Industry 4.0 solutions. Each technology is listed in either the country of its origin or the place of its application or the country of the related project coordinator.

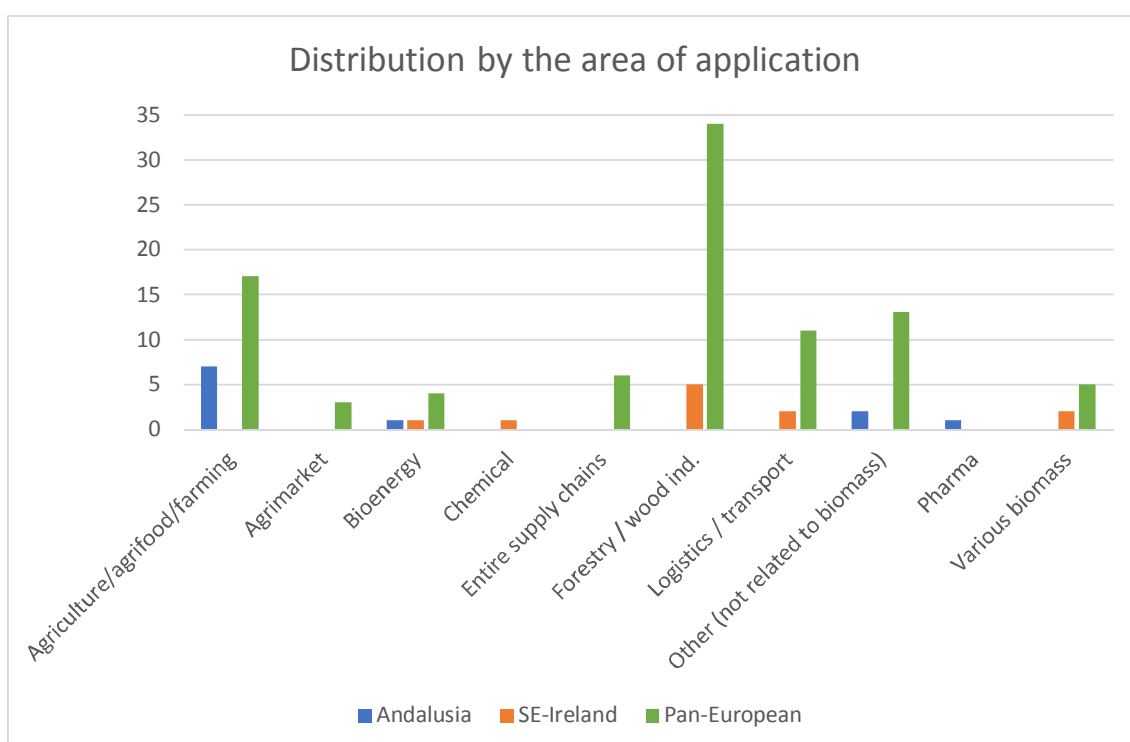


Fig: Distribution of technologies by the area of application. Each technology is listed in all applicable areas.

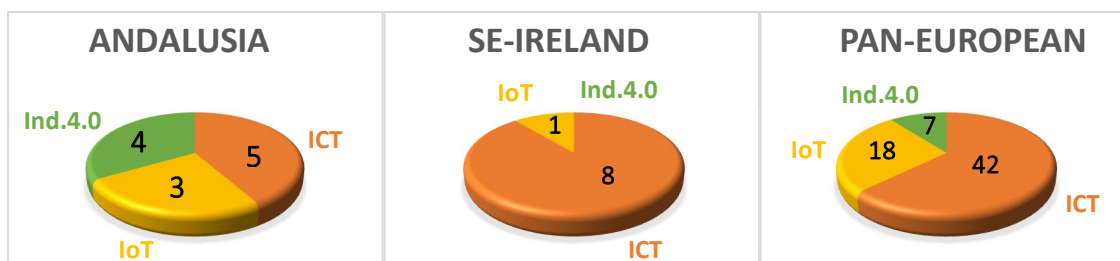


Fig: Subsector distributions. Each solution is listed in all applicable subsectors.

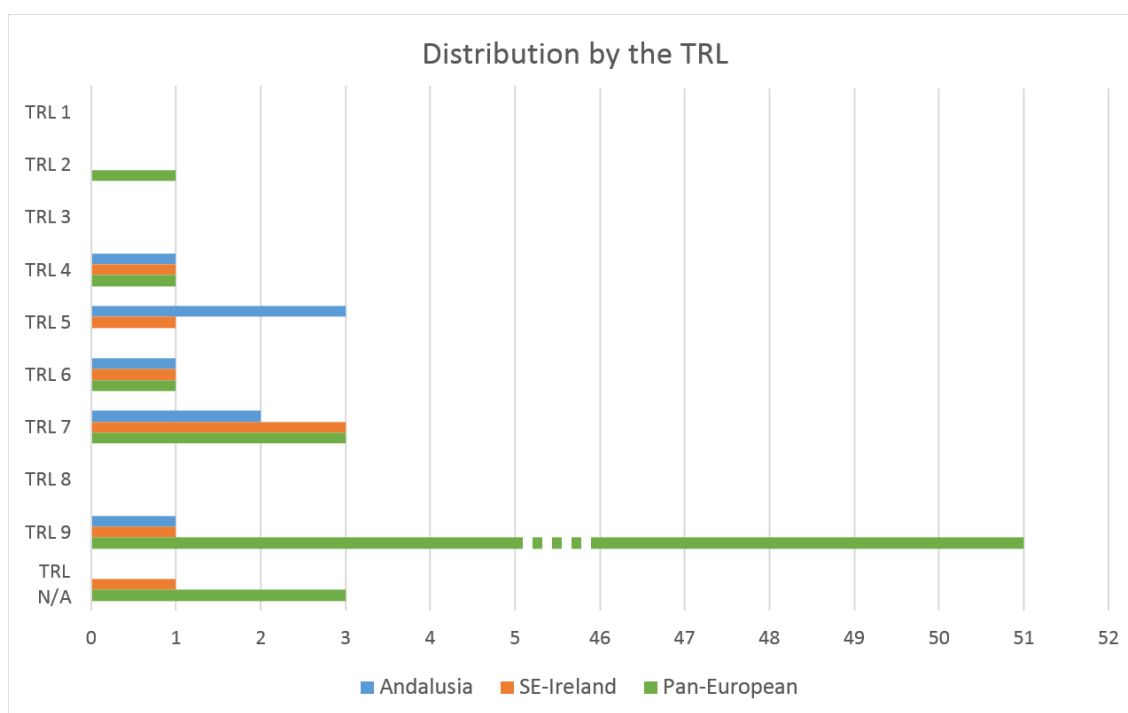


Fig: Distribution of the examples by the technology readiness level. For solutions with a TRL range assigned (e.g. TRL 7 - TRL 9), the maximum value (i.e., TRL 9) is used in the charts.

8. References

<https://cordis.europa.eu/projects/en>

<https://www.bbi-europe.eu/projects>

<https://www.electronics-notes.com/articles/connectivity/>

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