EIP-AGRI Focus Group

Sustainable industrial crops

STARTING PAPER - REPORT

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Objective

This EIP-AGRI Focus Group aims to collect and summarise knowledge and current practice in the area of 'Sustainable Industrial Crops in Europe' listing problems envisaged as well as opportunities. Focus Groups take stock of the status of the area in research and practice highlighting possible problems and innovative solutions to inspire, demonstrate and help the entire chain from farmer to processer achieve sustainable growth and profitability. Focus groups encourage and engage participation from a diverse range of stakeholders including farmers, industry professionals, advisors and researchers. This focus group aims to provide new and useful ideas to solve problems, particularly regards sustainable uptake of industrial crops and potentially initiate new Operational Groups or research projects.

Industrial crops can be defined as crops that provide raw materials for processing into non-food products. There is a significant move towards more sustainable bio-based building blocks for today's society which can be sourced from industrial crops. Limited resources and an ever-increasing world population that is hungry for more and more resources means novel approaches to adapt and develop raw materials for society are required. Furthermore, there is a conscious move within modern society to utilize renewable and sustainable materials in everyday living. This has driven a market rise in plant-based extracts for a number of industries particularly bioenergy, pharmaceuticals, cosmetics, fibres and plastics.

The predominant question of this Focus Group is "**How can industrial crops contribute to new market opportunities, business models and sustainable farming systems which create value for farmers in the EU, while not replacing food production?".** This will be achieved by completing the flowing tasks:

- **Collect practical and inspiring examples and good practices in growing industrial crops** in Europe while not replacing food production.
- **Identify existing value chains of bio-based materials where farmers have the potential to play a substantial role**, through long-term agreements or direct participation, while considering different bio-climatic conditions, agro-ecosystems and forms of cooperation along the chain.
- Discuss **strengths and weaknesses of the identified value chains**, notably with regard to the diversification of farmers' incomes and the environmental performance of the holding and of the whole value chain.
- **Suggest innovative business models** to foster integrated links between production/business/applied research.
- Identify further **research needs from practice** and possible gaps in technical knowledge.
- Suggest innovative solutions and provide ideas for EIP-AGRI **Operational Groups** and **other innovative projects**.

A key objective of the group is how to identify how to develop a supply chain of raw materials that has not jeopardised land that may be used for food production.

Overview of the topic

There are numerous exciting avenues being developed to utilize industrial crops for todays society that can be extracted from renewal and sustainable sources. There is a conscious move away from synthetic chemicals

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and fossil fuel derived materials to more sustainable products from renewable sources. This move also has extensive broader benefits to local communities and can foster rural and sustainable development. Industrial crops can offer an excellent substitute for traditional petroleum based raw materials while also improving farmers and local economies incomes.

For the successful and sustainable growth of the sector, there is a need to develop business models that allow the establishment and mobilisation of industrial crops to ensure a good return on investment for farmers and processers while also ensuring there is no competition with food production. Development of biobased industries and encouragement of industrial crops provides new markets for agriculture, accelerates market access, reduces dependence on fossil fuel-based industries and other imports of raw materials and encourages rural development and retention of population in rural economies.

Drivers in the area of Industrial Crops

Policy

Sustainable production of industrial crops in Europe is driven by a number of policies and commercial motivations. The Renewable Energy Directive[1] has made specific references to biofuels derived from industrial crops. The revised Directive has numerous references to the threat of biofuel producing crops being planted in high indirect land use change (ILUC) areas. Methods of abating the risk of land use change in areas with high carbon sinks has been addressed by limiting the amount of fuels derived from high ILUC areas that Member States can report and certifying biofuels derived from low ILUC areas.

Indirect Land Use Change (ILUC) can occur when pasture or agricultural land previously destined for food and feed markets is diverted to biofuel production. In this case, food and feed demand still needs to be satisfied, which may lead to the extension of agriculture land into areas with high carbon stock such as forests, wetlands and peatlands. This implies land use change (by changing such areas into agricultural land) and may cause the release of greenhouse gas emissions (CO_2 stored in trees and soil) that negates emission savings from the use of biofuels instead of fossil fuels.

There is a synergy that industrial crops offer between achieving improved economic margins for farmers while also displacing fossil fuel derived products from the market. Industrial crops not only offer the potential to displace less sustainable products on the market but offer some degree of carbon mitigation through their growth life cycle and their encouragement of more locally sourced materials. The most efficient use of land regards yields achieved and ensuring that food producing land is not removed from the system is paramount to the sustainability of the industry and is a consideration in a number of the European Sustainable Development Goals[2].

Agricultural Economies

Agriculture in Europe is traversing turbulent times at the minute with lower incomes achieved in farming than other sectors, higher cost of inputs, increasing costs associated with adaption to sustainability and climate change, high dependency on CAP payments and low level of diversification to mitigate risks. Industrial crops have the opportunity to offer alternative income streams to farmers and therefore protect against market fluctuations to some degree. Analysis of the sector from Eurostat [3] highlights the need to look at high value

[1] "Renewable energy directive | Energy - European Commission." **https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive**.
[2] "Sustainable Development Goals | European Commission." **https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals_en**.
[3] "Agriculture - Statistics Explained." **https://ec.europa.eu/eurostat/statistics-explained/index.php/Agriculture**.

activities to help European farmers improve incomes with a reduction of 4.6% on income per annual work unit (AWU) reported in 2018. The financial implications of reduced revenue per work unit in traditional farming may make the prospect of more profitable options like industrial crops more attractive to farmers.

Current Status of Industrial Crops in Europe

The area of industrial crops is relatively small for European farmers at the minute with only 4.7% of the agricultural output coming from industrial plants. This low uptake may be a result of a number factors including the relative infancy of the sector, a lack of knowledge around the area regards agronomy and its potential markets, time and resource commitments required to move into a new farming activity and the potential lack of access to land for new crops. A breakdown of land area dedicated to industrial for each member state as reported by Eurostat in 2016 is below.

Industrial crops (land area in hectares in 2016)	% of Arable Land	Country
154,370	5.7	Romania
127,500	8.6	Poland
121,330	20.6	France
74,630	8.7	Italy
69,280	15.7	Greece
57,760	17.8	Germany
51,270	9.4	Spain
49,230	14.5	Hungary
36,920	45.7	Bulgaria
22,180	18.7	Austria
19,390	13.3	Croatia
16,630	13.4	United Kingdom
8,220	11.3	Slovenia
7,980	5.4	Lithuania
7,480	16.2	Denmark
6,070	9.8	Finland
5,760	19.0	Czechia
4,930	7.0	Sweden
3,640	9.0	Belgium
3,330	12.8	Slovakia
2,860	1.7	Portugal
2,260	4.2	Latvia
1,610	3.5	Netherlands
1,570	12.4	Estonia
750	3.4	Ireland
340	15.9	Luxembourg
220	1.3	Cyprus

Table 1. Breakdown of reported area of industrial crops in Europe in 2016 and percentage of arable land[4].

[4] "Data - Eurostat - European Commission." https://ec.europa.eu/eurostat/web/agriculture/data.

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Where to Grow Industrial Crops – Marginal Lands?

A key factor for the sustainable growth of the sector is that industrial crops do not replace food crops and jeopardise the capability of European soils to feed an ever-growing population. A number of initiatives have addressed this concern through researching the use of underutilised soils throughout Europe. Marginal soils are generally considered too unproductive to supply a meaningful quantity of economically feasible food crops and therefore are left fallow. Industrial crops have a unique profile in that some crops can provide relatively good yields on poorer soils with minimal external inputs. They also have high value end uses that can absorb reduced yields in some cases. The utilisation of marginal land for industrial crops ensures there is no conflict between food and commercial crops. One such project that is building a database of examples of resource efficient industrial crops and highlighting areas of land that are deemed marginal and underutilised which could potentially be used for industrial crops is the MAGIC project (Marginal lands for Industrial Crops project). The below graphic (figure 1) from the MAGIC project highlights some key areas for crops production on marginal lands.

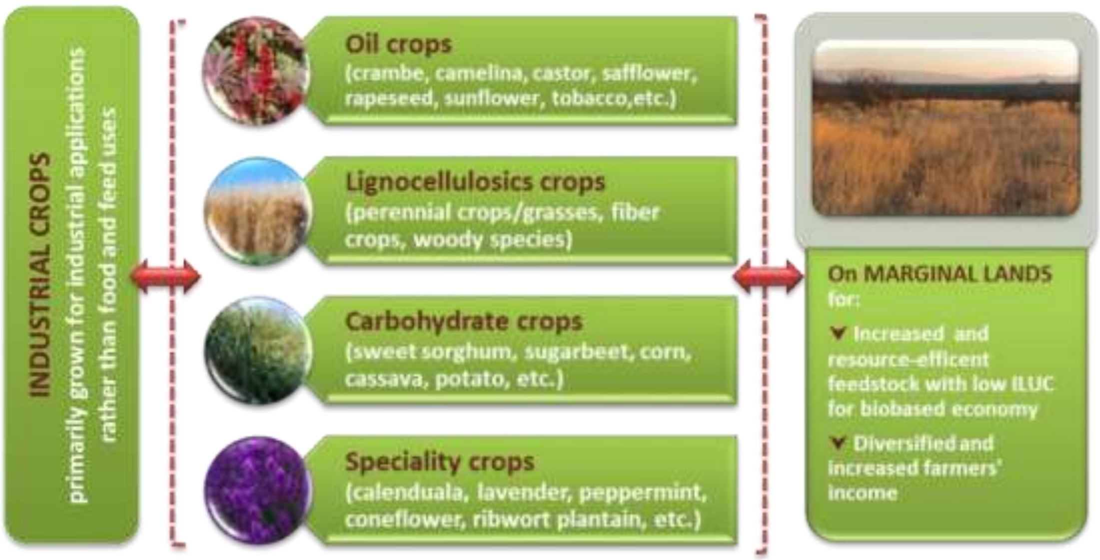

Figure 1. Potential end uses from crops grown on marginal lands [5].

The MAGIC project has estimated that 29% of land in Europe can be classified as marginal and may have the potential to be used in an industrial crops business model without competing with traditional food production. The diversity and resilience of some industrial crops allow them to grow in adverse conditions. A key aspect of the work MAGIC carries out is that the appropriate crops are allocated to appropriate areas. The programme has identified and classified land into different reasons for it being marginal. The most common reason for land to be classified as marginal is the rooting limitations (12%). This is followed by adverse climate and excessive soil moisture occurring in respectively 11% and 8% of the agricultural land. The limitations of marginal lands have been classified by the MAGIC project into six headings as below:

1. Adverse climate (low temperature and/or dryness)
2. Excessive wetness (Limited soil drainage or excess soil moisture)
3. Low soil fertility (acidity, alkalinity or low soil organic matter)

[5] "Project overview - Magic." http://magic-h2020.eu/project-overview/.

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4. Adverse chemical conditions (Salinity or contaminations)
5. Poor rooting conditions (low rootable soil volume or unfavourable soil texture)
6. Adverse terrain conditions (steep slopes, inundation risks)

The MAGIC [6] project has developed a valuable decision support system to help landowners and farmers identify the potential crops that are suitable to marginal lands throughout Europe.

Other approaches to ensure sustainable uptake of industrial crops could involve co cropping industrial crops and food crops. A number of industrial crops can be used as cover crops and break crops for tillage ground and could potentially optimise the efficiency of tillage land. There are also initiatives in member states like agroforestry that industrial crops may be able to use as examples. Industrial crops could be grown on the typically redundant headlands of food crop fields or as buffer strips. Some industrial crops can improve soil structure and improve soil profiles significantly and may have the potential to enable more land to become available for food production in the future by growing the crops in partnership. Some crops like hemp and sugar beet that are grown for food production but do not reach the quality standards can be redirected to industrial production reducing waste and adding revenue streams for farmers.

Break crops like oil seed rape that can be used for biofuel production are used in some scenarios to help improve yields of wheat. Growing oil seed rape on traditional tillage ground for a season reduces the incidences of funguses that affect food crops and improves nitrogen efficiencies in the soil resulting in greater yields in subsequent years.

Discussion Questions

- What sustainable business models can be identified using the MAGIC database?
- What potentials can co cropping offer? Can industrial crops be used to improve efficiencies in traditional food producing crops?

Market for Industrial Crops

The number of crops that are available to be used in alternative industries is vast and the potentials far exceed the current knowledge and applications. There is a need to develop understanding and research in the extensive potential of bio-based products derived from crops. Society is in the very early stages of comprehending the potential of this sector and as petroleum-based products become less favorable in developed countries greater resources will be dedicated to alternatives. The success and progression of the sector is dependent on a profitable market for industrial crops. Some crops will satisfy a number of markets and thus adding increased profitability to the associated enterprises. Some potential markets are outlined below.

Bioenergy

The traditional method of utilising crops for bioenergy has been the direct combustion of the biomass to generate heat. Biomass can be directly combusted in a number of ways and the potential energy that can be generated is dictated by a primary factor - the calorific value of the crop. The calorific value of a crop is dependent on a number of conditions, mainly the physiology of the plant, the moisture content at combustion and the suitability of the crop for combustion. Heat can be utilised for direct thermal use or can be channeled to create steam and generate electricity through a turbine.

[6] "MAGIC – Marginal Lands for Growing Industrial Crops ...." **http://nova-institute.eu/project/h2020-magic-marginal-lands-growing-industrial-crops-turning-burden-opportunity/**.

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Liquid and gas biofuels can also be produced from industrial crops through preprocessing of crop biomass. A number of methods can be employed to extract products like bio ethanol and biomethane form industrial crops like enzyme extraction and anerobic digestion.

Traditional biofuels would have been extracted from crops like sugarcane, wheat and rapeseed but these are food crops that require fertile land to grow and producing biofuels from these directly conflicts with food production. Research is ongoing on extracting biofuels from crops like miscanthus, switchgrass and sorghum for example. These crops have a much better ability to utilise marginal land through their increased ability to photosynthesis with reduced nutrients, reduced water requirements and capability to use carbon dioxide more efficiently.

Pharmaceuticals

There is an increasing market for pharmaceutical extracts from sustainable and renewable sources. Industrial crops not only play an important role in providing raw materials for drug production but are an important method of discovering and development of new drugs[7]. A wide range of plant extracts can be processed from industrial crops including salicin from willow bark which can be processed into aspirin. Codeine and morphine can be sourced from poppy plants.

Cosmetics

Many cosmetics already contain a significant proportion of extracts from plants and the sector is expected to grow exponentially as people look for more natural cosmetic products. It is reported that a minimal amount of cosmetic extracts come from industrial crops and instead are extracted from wild plants [8]. There is excellent potential for industrial crops to improve efficiencies in this area due to scale of operations and smoother harvesting of crops for production. Crops like plantain that are used in the cosmetic industry can grow well on marginal land and can offer good returns on investment for underutilised land.

Fibers

A wide number of industrial crops are very suitable for processing into raw materials for a number of fiber industries including textiles, building materials and paper/pulp production. This area has garnered increasing interest due to the potential flexibility and biodegradable nature of fibers sourced from crops as opposed to petroleum-based products[9]. There is also a shortage of forestry raw material for building and paper/pulp production so the introduction of industrial crops to the market may alleviate this pressure. Growing crops like willow and eucalyptus for pulp production has many benefits. These include the ability of the crops to grow on marginal land but also their physiology allows them to be processed in a more efficient manner improving profitability margins for farmers and processers.

Plastics

Plastic products have traditionally been manufactured with petroleum raw materials and have very poor environmental profiles due to their longevity in the environment and their carbon intensive sources. Industrial crops have huge potential to supply the bio plastics and bio polymers industry significantly. Crops with very high lignocellulose proportions like sugar cane were

> Trials are currently being carried out on growing camelina with crops like winter oilseed rape. The cropping cycle for camelina is short at 80 to 90 days which facilitates two crops being grown on the same land in the one year. Camelina can be supplied to the plastic and polymers industries as a raw material.

[7] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3560124/
[8] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/fg35_starting_paper_2019_en.pdf
[9] https://cordis.europa.eu/project/id/311965/reporting

previously used for bio plastic production of packaging but the use of food crops that require good land is an issue for farmers in the European Union. Alternatively, increasing research is being carried out on utilizing crops like switchgrass and camelina on marginal lands to supply the market.

Other Dynamic End Uses

Many crops have numerous avenues they can be processed into as displayed by the below graphic which highlights the number of end products that can be extracted from Miscanthus and Hemp crops. The GRACE-Project (GRowing Advanced industrial Crops on marginal lands for biorEfineries) is testing ten innovative approaches to optimising miscanthus and hemp supply and production chains throughout Europe (also on underutilised and marginal land). Figure 2 shows the broad array of products that can be extracted from Miscanthus and Hemp.

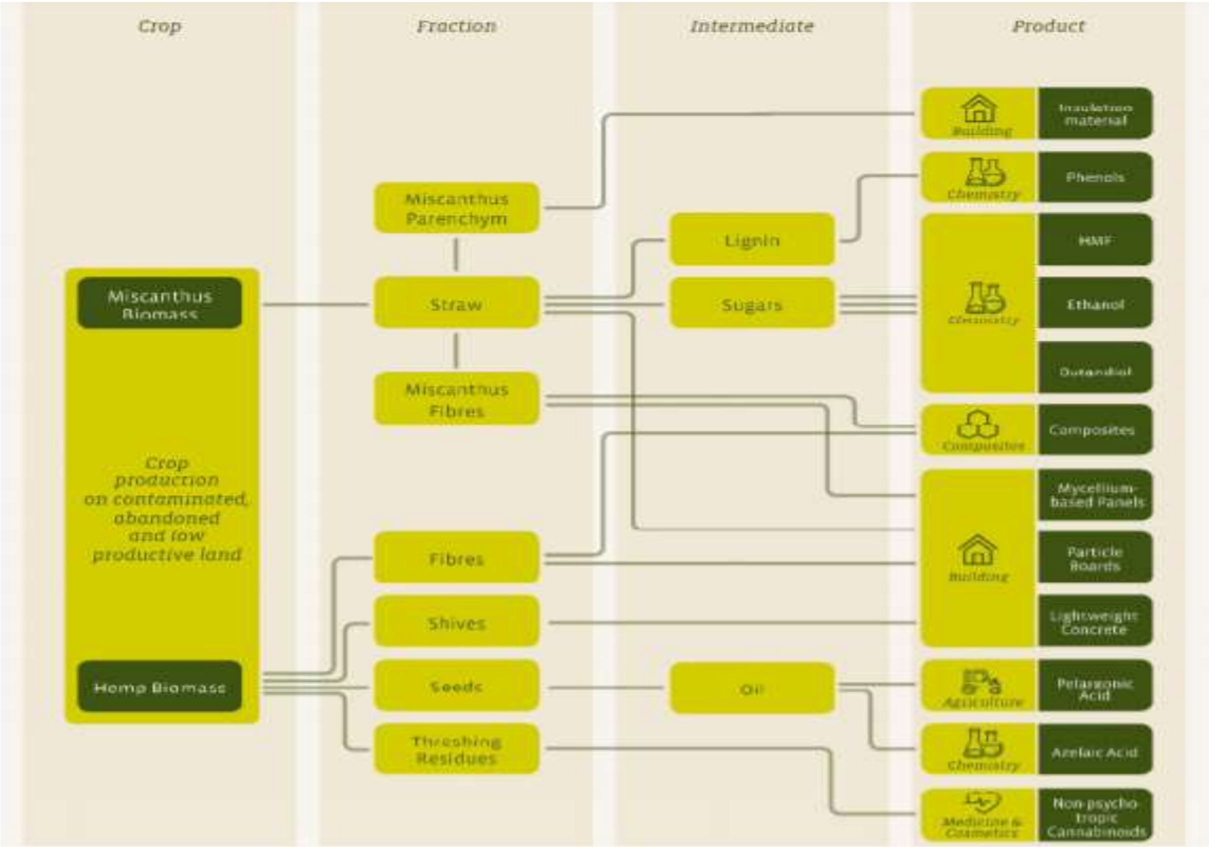

Figure 2. GRACE production process for miscanthus and hemp and high value end uses[10]

Nickel Extraction

The market for extracted minerals like nickel has seen an increase in demand in the last decade due to the uptake of electric cars. This has raised ethical and sustainability questions surrounding the sourcing of this mined mineral because of the method of traditional extraction. New research into utilizing hyperaccumulators like yellow tuft alyssum[11] on poor soils have released exciting results with estimates of 200kg of nickel being extracted from poor soils with minimal additional investment for farmers required. Traditional farm machinery

[10] "GRACE | Bio-Based Industries - Public-Private Partnership." **https://www.bbi-europe.eu/projects/grace**.

[11] "Rubber dandelions and nickel-eating flowers | Horizon: the ...." **https://horizon-magazine.eu/article/rubber-dandelions-and-nickel-eating-flowers.html**.

can be utilized to harvest and process these flowers reducing the requirement for excessive capital investment.

Rubber Production

Traditional rubber is typically imported from Asia with over 90% of natural rubber being imported into Europe. This has left the European market susceptible to fluctuations in supply, cost and sustainability of importing rubber. New research has now identified a species of dandelion that contains up to 15% rubber in its roots that can be grown throughout Europe and help satisfy some of the market requirements. While rubber is recognized as the predominant high value use for dandelions at the minute it is worth noting that there are multiple potentials that a crop like dandelions can offer also from pharmaceutical extracts to their contribution to biodiversity (dandelions are an excellent source of pollen and nectar for pollinators[12]).

Discussion Questions

- Identification of a wider range of end uses for crops and how to measure non-monetary benefits of crops?
- How to ensure the most profitable, suitable and sustainable crops are adapted?
- Adapting a decision matrix to help farmers allocate land and effort to the correct crops? Maybe the MAGIC matrix could be utilised?

Agronomy of Industrial Crops

The sustainability of industrial crops depends on a number of factors. A factor that not only applies to traditional agriculture but also industrial crops is the efficiency of the growth of the crop. The highest possible yields from each hectare planted not only ensure reduced energy and financial inputs but also that the sustainability of the crop will be ensured. Improved efficiencies ensure an attractive return on investment for farmers and application of best practice will ensure crops are produced in a sustainable way. Yields from different crops vary significantly. Simply comparing biomass yields is not representative of the final contribution of the crop and does not take into account potency, calorific value/fuel density or value. A method to measure the productivity of each contribution from industrial crops may be required to quantify the sustainability and efficiency of crops.

A number of industrial crops have adapted to growing on poorer and marginal soils. Crops like miscanthus and switchgrass have adapted to dry growing conditions while crops like willow can grow in much wetter conditions and achieve good yields were other crops may struggle. Willow is a very low input crop (the leaf fall in the winter returns 40% of nutrients back to soil) and fertilisers like Wastewater Treatment Plant (WWTP) sludge are excellent to fertilise the crop. The crop is multi beneficial regards its very high evapotranspiration rates and buffering capabilities allowing the crop to not only produce an array of products but also improve water quality and soil structure of land. A variety of research has been carried out on willow breeding where certain varieties have been identified to yield well on marginal soils[13]. Crops like giant reed can grow on soils contaminated with cadmium and nickel bringing land that would traditional have been abandoned into production once more.

Harvesting of crops will vary greatly depending on their individual growth patterns and structure. A number of industrial crops can be harvested using adapted machinery that is currently used to harvest forage crops and significantly reduce capitol costs for farmers.

[12] "Food for Pollinators: Quantifying the Nectar and Pollen ...." 24 Jun. 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4920406/.
[13] https://www.sciencedirect.com/science/article/abs/pii/0144456586900557

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Discussion Questions

- How to measure the efficiency and sustainability of crops and their outputs?
- Best agronomy approaches for establishing crops and best harvesting approaches?

Processing of Industrial Crops

The variety of the potential crops means a one size fits all approach is not feasible for processing crops. A bespoke approach to processing crops like willow where bark separation may be required to extract compounds and utilize biomass efficiently will not suit other crops like hemp and lavender. Therefore, a cooperative approach to growing and processing crops where centralised facilities are located locally to crops and end users would be the most sustainable approach. This may not be possible in all cases where large quantities of raw materials may be required and therefore larger industries may be required for economies of scale and financial feasibility. Factors like transportation distances and entire life cycle assessments may be required to ensure the sustainability of the crop and process is upheld.

Processing of crops like willow and eucalyptus involve a number of steps beginning with harvesting in the field. There are two options for harvesting a crop like willow using an adapted forage harvester and chipping the plant or using a whole stem harvester. This material is then brought to the processing facility where it will go through mechanical processing to try and remove as much bark as possible (if bark removal is not possible the material can be soaked for a period of time to extract pharmaceutical compounds). The main component of the material will then go on to a cooking, processing and screening step. There are two product streams that occur at this step – pulp and lignan. Pulp can be processed into a number of paper-based products.
In the process of extracting lignan from the material a byproduct called black liquor is produced, this can either be burned in recovery boilers to feed energy back into the process or can be extracted to produce biofuels. The lignan now goes on to be further processed through evaporators and screens. This lignan can be further processed into a number of products like bio-based resins, adhesives, composites or biofuels[14]. A single harvest of willow every two to three years can provide three revenue streams for farmers and processers.

Discussion Questions

- Localised processing and cooperative models versus feed into large industries?
- Identifying high value end uses for crops that are suitable to local conditions?
- Could a user-friendly Life Cycle Assessment of processes and sustainability accreditation be developed for the sector?

Challenges for the Sector

A cooperation among stakeholders is paramount to the success of the industry and key to mobilising crops. An example of this recognition is in the bioenergy sector where the International Energy Agency[15] has identified one of the critical success factors for the bioenergy sector is bringing together key stakeholders normally operating in different market sectors like agriculture and forestry, transportation fuels, chemical and

[14] https://www.sciencedirect.com/science/article/abs/pii/S0014305718320597
[15] "Home - Task 42." http://task42.ieabioenergy.com/.

pharmaceutical industries and energy into multi-disciplinary partnerships to discuss common biorefinery-related topics, to foster necessary R&D direction and to accelerate the deployment of developed technologies.

Appendix

Common name	Current uses	Innovative applications
Switchgrass	Forage, CHP, erosion mitigation, wildlife habitat	Advanced biofuels, bioplastics, phytoremediation
Camelina	Aquaculture, cosmetics, aviation fuel, winter cover crop	Hydraulic fluids, biopolymers
Calendula	Pharmaceutical, Cosmetics, Painting, Ornamental	Agriculture, Dyes
Miscanthus	Solid fuel, Building material (Isolation, thatching, panels), animal bedding, biocomposites	Biogas, isobutanol (under investigation), erosion mitigation, other ecosystem services
Ribwort plantain	Pharmaceutical, Food	Cosmetics, Textiles
Giant reed	Fences, roofs, music instruments, paper	Advanced biofuels, bioplastics, non-wood materials, phytoremediation, erosion mitigation, other ecosystem services
Tall wheatgrass	Forage, erosion mitigation	
Amaranth		Biogas, phytoremediation, phytomining, other ecosystem services (landscape heterogeneity, biodiversity and pollinators)
Ethiopian mustard	Biofuel	Aviation fuel
Hemp	Textiles, ropes, composites materials, insulation mats, car interior panels, reinforce expanded starch foams in the food packaging sector, hemp concrete	Advanced biofules, biogas, secondary metabolites (cannabinoids, terpenoids and flavonois for pharmaceutical applications), bio-pesticides against nematodes, mesophilic fungi, insects and potentially weeds
Common reed	Water treatment, roof thatching, paper and pulp, energy (combustion and biogas), litter	Bioconstruction material, polymerisation for textile or plastic, advanced biofuel
Spanish broom	Ornamental plant, biomass	Fibre
Nettle	Fibre, Clothing, Cosmetics.	
Cardoon	Traditional Food, Forage, CHP, erosion mitigation, wildlife habitat	Advanced biofuels, bioplastics, phytoremediation, Oil based products
Pennycress	Biofuel	Aviation fuels
Willow	Comustion/CHP, erosion mitigation, wildlife habitat	Advanced biofuels, phytoremediation, pharmaceutical extracts, paper pulp,
Eucalyptus	Cellulose and paper industry,	cellulosic ethanol, phytoremediation,

	fuelwood, charcoal, poles, shelterbelts, railway sleepers and hardboard production	biodiversity, bark for tannin and rutin, leaf oil for industrial purposes and pharmaceutical applications
Siberian elm	Ornamental plant, biomass	
Wild sugarcane		Advanced biofuels, bioplastics, non-wood materials
Lupin	Pharmaceuticals/cosmetics	
Jerusalem artichoke	alcohol, fructose, fresh tubers, animal feed	Pharmaceuticals, biofuel
Sunn hemp	Green manure, cover crop, nematode suppressor, fiber crop	Advanced biofuels, bioplastics, phytoremediation
Caper spurge / euphorbia	Biofuels, paints, varnishes, adhesives, industrial coatings, medicinal and pharmaceutical product	Industrial applications like epoxy coatings and resins; pharmaceuticals.
Sugar beets		Advanced biofuels, butanol
Dandelion	Biodiversity benefits	Rubber
Alyssum	Biomass	Nickel extraction
True lavender, English lavender Lavandin	Essential oil; perfumes, pharmaceuticals, cosmetics, personal care and home maintenance products	Aromatherapy, integrative medicine,

Table 2. List of some industrial crops and their associated and potential uses[16] [17].

[16] "(PDF) Crops2industry PROJECT FINAL REPORT." https://www.researchgate.net/publication/324830392_Crops2industry_PROJECT_FINAL_REPORT.
[17] "Home-MAGIC." http://magic-h2020.eu/.

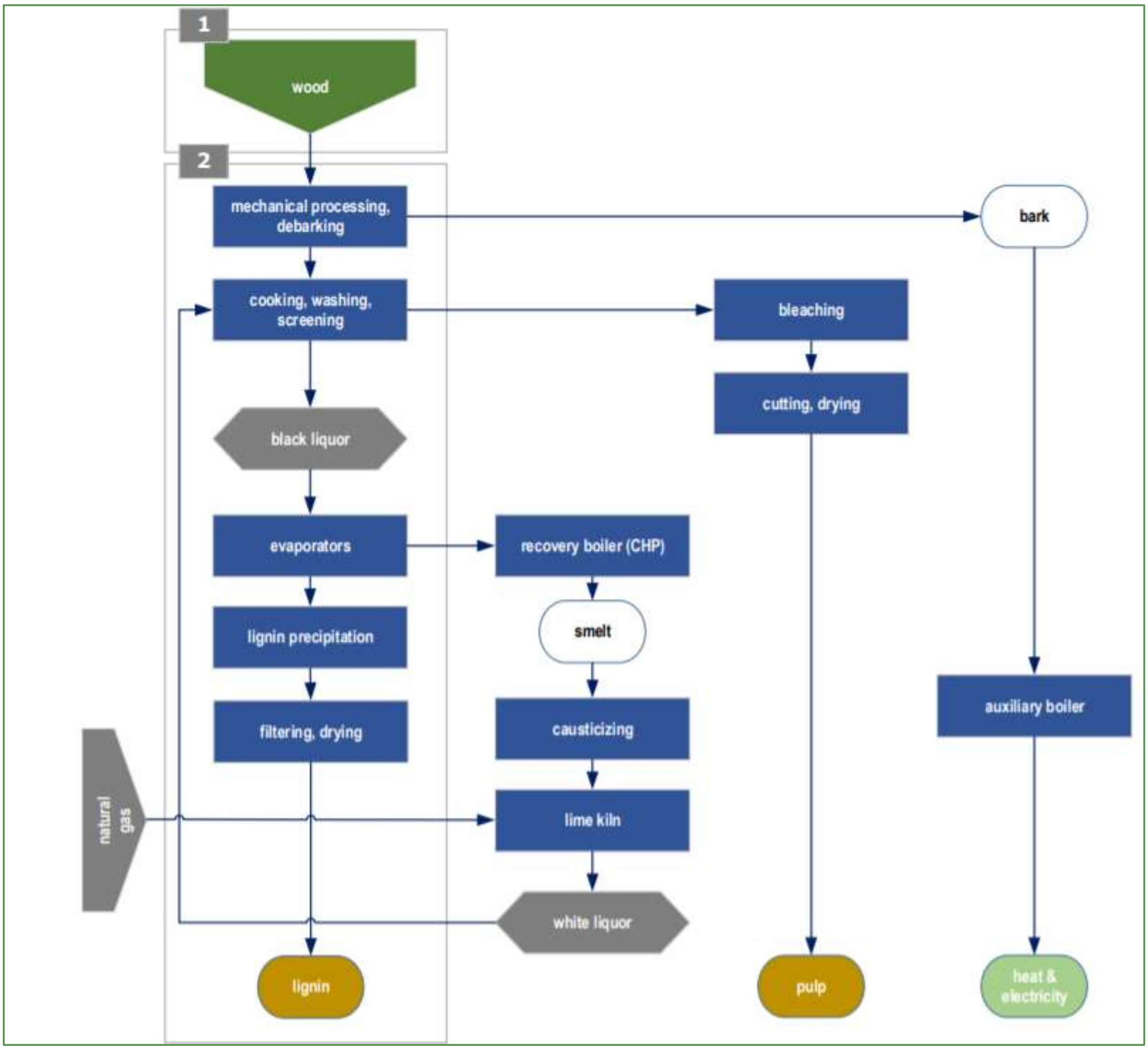

Figure 3. Diagram of processing flow for wood and potentially biomass-based crops like willow, poplar and eucalyptus[18] .
Biomass crops like willow and eucalyptus can be processed in a very similar way to the diagram above with an immense potential for additional outputs including bio pharmaceuticals and cosmetics along with lignan, pulp and bioenergy outputs. These materials can go to a number of manufacturing processes and means diversified revenue streams for farmers and processers.

[18] "Home - Task 42." http://task42.ieabioenergy.com/.

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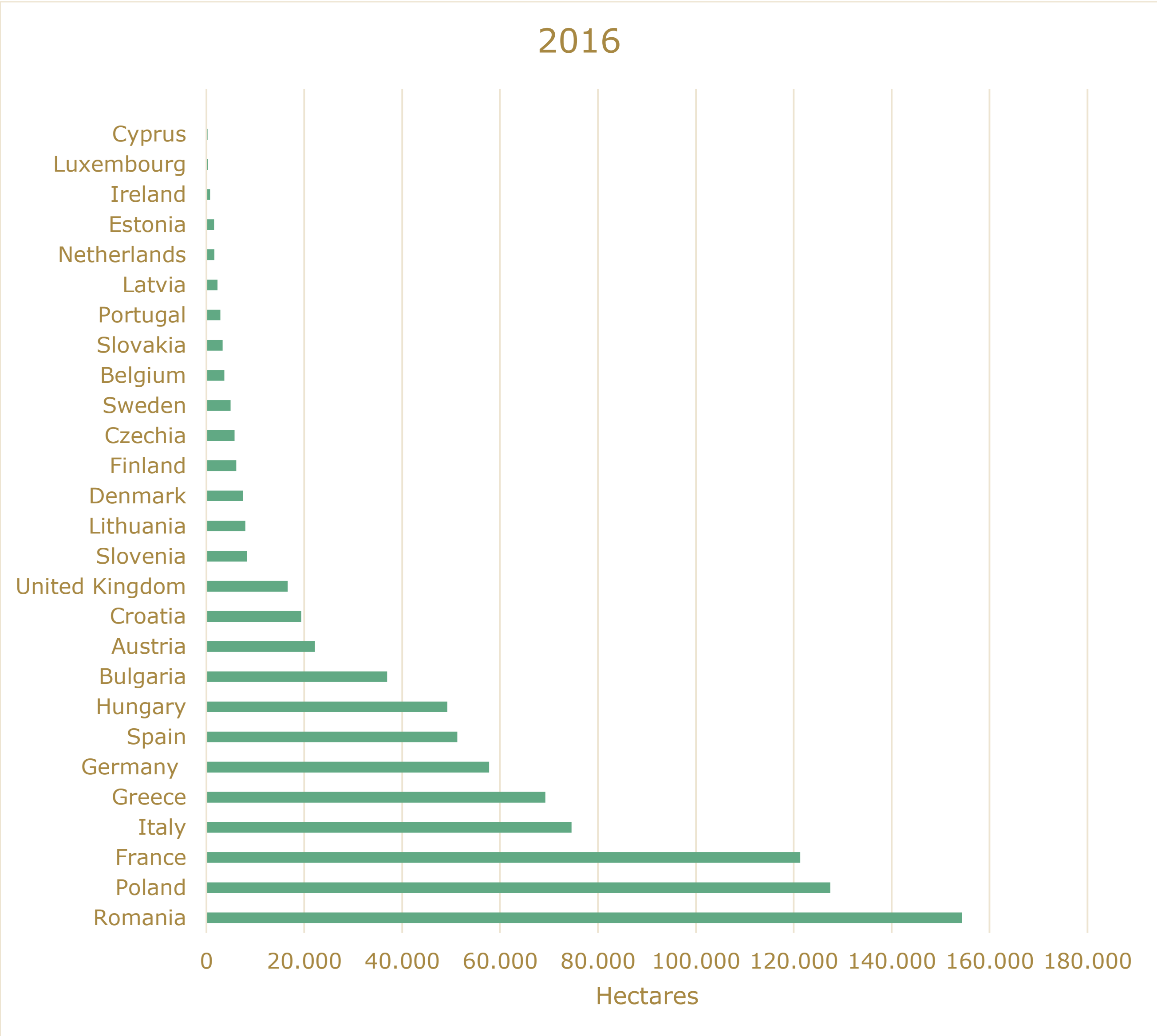

Graph 1. Land area in industrial crops

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