Marginal lands for Growing Industrial Crops

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1 Publishable executive summary

This section should be of suitable quality to enable direct publication by the Commission. Please ensure that it is set out and formatted so that it can be printed as a stand-alone paper document not exceeding four pages. It shall also reflect the website of the project (if applicable).

Please include a summary description of the project objectives, a description of the work performed since the beginning of the project, a description of the main results achieved so far, the expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far). You should update this publishable summary at the end of each reporting period.

Please include also, as appropriate, diagrams or photographs illustrating and promoting the work of the project, the project logo and relevant contact details.

The address of the project public website should also be indicated, if applicable.

2 Introduction

The aim of this work is to combine value chain analysis with the UNEP/SETAC methodology for Social Life Cycle Analysis (S-LCA) and the Hotspot Analysis Tool for Sustainable Consumption and Production (SCP) and perform a social and socio-economic LCA for a set of biobased value chains selected within the Magic project. The research presented in this paper is grouped in two parts:

- Part A investigates the social implications from specific biobased value chains which use as feedstock crops grown in marginal land, and
- Part B uses the consistent datasets from the Hotspot Analysis Tool for Sustainable Consumption and Production and identifies social opportunities at national level for EU27 & UK.

Information for the performance of the selected crops is based on literature (included in references) and on:

- Alexopoulou, E., Christou, M., Eleftheriadis, I. (2018): Handbook with fact sheets of the existing resource-efficient industrial crops (Deliverable D1.5). In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, CRES, Athens, Greece. http://magic-h2020.eu/documents-reports/
- Alexopoulou, E., Rettenmaier, N., Wagner, T., Reinhardt, G., Vikla, K., Spekreijse, J., Piotrowski, S., Dubois, J.-L. (2020): Report on system description of selected value chains (Deliverable D6.2). In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, CRES, Athens, Greece. http://magich-2020.eu/documents-reports/
- Panoutsou, C., Singh, A., Christensen, Th., Alexopoulou, E., and F. Zanetti. (2021). Deliverable D4.1 Training Materials for Agronomists and Students. In PANACEA reports, supported by the EU's Horizon 2020 programme under GA No. 773501. Imperial College London, London, United Kingdom. http://www.panacea-h2020.eu/wp-content/uploads/2021/04/D4.1-Training-manual-for-agronomists-and-students-update-.pdf
- Panoutsou, C., Singh, A., Christensen, Th., Alexopoulou, E., and F. Zanetti. (2021). Deliverable D1.3 D1.3 Strength and opportunities of nearto-practice non-food crops (NFCs). In PANACEA reports, supported by the EU's Horizon 2020 programme under GA No. 773501. Imperial College London, London, United Kingdom. http://www.panacea-h2020.eu/wp-content/uploads/2021/04/D1.3-Strengths-opportunities-of-NFCs-FINAL-.pdf
- von Cossel, M., Iqbal, Y., Scordia, D., Cosentino, S. L., Elbersen, B., Staritsky, I., van Eupen, M., Mantel, S., Prysiazhniuk, O., Maliarenko, O., Lewandowski, I. (2018): Low-input agricultural practices for industrial crops on marginal land (Deliverable D4.1). In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, University of Hohenheim, Stuttgart (Hohenheim), Germany. http://magic-h2020.eu/documents-reports/

3 Approach

The work provides a conceptual link of Value Chain Analysis (VCA) and Social Life Cycle Analysis (S-LCA) and further employs consistent datasets at national level through the Hotspot Analysis Tool for Sustainable Consumption and Production to understand socially relevant opportunities that the understudy biobased value chains can offer to European regions. The tool allows to analyse hotspot areas of sustainable consumption and production, in a consistent and transparent manner, and evaluate the social opportunities of rehabilitating marginal land and cultivating industrial crops across the different national contexts.

3.1 Value Chain Analysis (VCA)

Biobased value chains involve complex, cross sectoral interactions between their upstream and downstream stages. Moreover, their suitability, efficiency and appropriate implementation scales depend on geographical and climate features, so their optimal performance tends to be region and case specific.

Decision making for their establishment and operation should therefore be based on the analysis of challenges and key decision issues for each value chain stage, reflect their relevant merits and disadvantages and use the evidence provided to optimise synergies and drive positive behaviours.

Value chain analysis has been introduced Porter to represent internal activities involved with producing goods and services. The approach applies a systemic strategy to analyse internal value chain activities, understand challenges and identify competitive advantages and disadvantages. Value chain analysis fits well with the dynamic structure of the bioeconomy which has interrelated stages for production and use of biological raw materials. It can be applied to understand the system and focus the assessment to stages, and activities; identify challenges that trigger major uncertainties and articulate metrics suitable to overcome them and; evaluate differentiation strategies to incentivise development, identify their risks and define their competitive advantage.

3.2 Social Life Cycle Analysis (S-LCA)

S-LCA is recognised as the social equivalent to environmental LCA[1]. It can operate from cradle-to-grave and addresses social impacts within specified stages of a value chain at local

[1] Sala S., Vasta A., Mancini L., Dewulf J., Rosenbaum E. 2015. European Commission, Joint Research Centre, Social Life Cycle Assessment: State of the Art and Challenges for Product Policy Support, Publications Office, Luxembourg, http://bookshop. europa.eu/uri?target=EUB:NOTICE:LBNA27624:EN:HTML

and global scales[2]. Its systemic approach aligns well with biomass supply and value chains for bioeconomy integration at territorial level or in specific sector-product systems[3] [4].
The work has also adopted a participatory approach. A series of interviews and surveys through online webinar activities has been performed to:

- Understand and decide important challenges that restrict the development and implementation within and across the value chain stages, and
- Agree on S-LCA impact categories that relate to the challenges and select indicators that are relevant to the social implications of the value chain's performance but can also be associated to the stakeholder groups (in the case of Magic: farmers, value chain actors and local community).

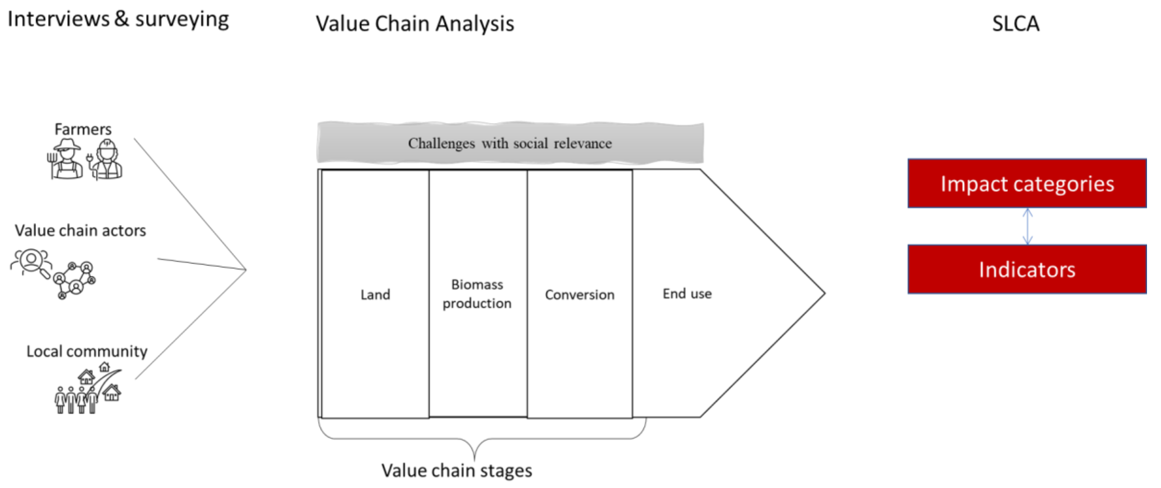

Figure 1: Conceptual link of the approaches used in the S-LCA for the Magic project

The work in Magic adopted the UNEP SETAP life cycle initiative principles and did not perform only a Social Impact Assessment (SIA). The reason is that the social impact assessment (SIA), which is used to analyse any intended or unintended social impacts of a planned policy, program or project, defines social impact as 'consequences to human populations. Biobased value chains involve a dynamic value chain process which is strongly interrelated to the decision-making steps from stakeholders. The UNEP SETAP approach adds another dimension to social impacts, which is, the role of the stakeholders, so it has been considered more appropriate for the cases in Magic.

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[2] Feschet P., Macombe C., Garrabé M., Loeillet D., Saez A.R., Benhmad F. 2013. Social impact assessment in LCA using the Preston pathway. Int J Life Cycle Assess 18, 490–503. (DOI 10.1007/s11367-012-0490-z)
[3] Panoutsou C, Singh A, Christensen T, Pelkmans L. 2020 Competitive priorities to address optimisation in biomass value chains: the case of biomass CHP. Global Trans. 2, 60–75. (doi:10.1016/j.glt.2020.04.001)
[4] Sala S, Vasta A, Mancini L, Dewulf J, Rosenbaum E. 2015 European commission, joint research centre, social life cycle assessment: state of the Art and challenges for product policy support. Luxembourg, Europe: Publications Office. See http://bookshop.europa.eu/uri?target=EUB: NOTICE:LBNA27624:EN:HTML

The respective definition for social impact is:
'*Consequences of social relations (interactions) weaved in the context of an activity (production, consumption or disposal) and/or stimulated by it and/ or by preventive or reinforcing actions taken by stakeholders (ex. enforcing safety measures in a facility). Therefore, social impacts are dimensions of stakeholders relations affected positively or negatively by one of the stages in the life cycle of a product*[5]. (Mazjin, 2008)'

[5] Mazjin, B. B. (2008). Code of Practice for a social-economical LCA (seLCA) for product assessment - Fourth Draft.

4 Value chain analysis

The work performed in Magic followed a bottom-up concept (ref value chain and Siebert) and focused on understanding challenges, potential impacts and value creation along the value chain within the context of European regions.

Several challenges have been identified within value chain stages through a set of selected interviews and online surveying. The main ones are summarised below and in Table 2.

Land use: Most biomass feedstocks are land-based, being sourced from agriculture and forest systems. The main activities in this stage are land acquisition and soil management. Decision makers face challenges including the need to avoid displacement of other land-based activities and the need to ensure sustainable practices that can prevent soil erosion and improve soil management.

Biomass production includes the following activities: crop establishment and management, harvesting, pretreatment (chipping, drying, milling, briquetting, etc.), storage and transport. Crop establishment and management practices must recognize and enhance biodiversity, enable low input cultivation systems, and minimise intensity of the applied practices.

Conversion pathways of biomass to biobased products include biochemical, thermochemical and physical or chemical depolymerisation. The main activities are the construction and operation of conversion installations. Challenges with regards to construction include site selection, technological readiness of the conversion pathway and market prospects. With regards to operation, challenges include low emissions performance, handling mixed volumes of feedstocks and improving synergies for valorisation of residues and co-products.

End use of biomass-based products includes activities related to distribution and consumer use. Products should be compatible with existing infrastructure, standards and distribution channels. Furthermore, both consumer acceptance and successful market uptake will be subject to their fitness to substitute existing products and commodities in sectors as chemicals, food, energy, fuels, etc.

Table 1 Challenges across value chain stages and potential roles of stakeholders

Value chain stages	Challenges (as defined through interviews and surveying)	Farmers	Value chain actors	Local community
Land use	Access to neglected natural resources	Ensure sustainable practices that can prevent soil erosion and improve soil management	Avoid displacement of other land-based activities	Reduce GHG Foster carbon conservation and sequestration
Biomass Production	Safeguard planetary boundaries Social and economic resilience in rural areas	Improve biodiversity with sustainable cropping practices	Facilitate the supply of non-food crops for bioeconomy	
Conversion	Advanced and efficient technologies are not supported enough. Lack of awareness in SMEs and industries for transition pathways to bioeconomy[6]		Appropriate site selection Select mature conversion pathways Improve synergies for valorisation of residues and co-products	
End use	Low awareness of benefits and usability of biobased products		Ensure biobased products are compatible with existing infrastructure, standards and distribution channels	Enhance social inclusion
Across all stages	Lack of awareness; lack of clarity for strategic decision making	Improve knowledge transfer		
	Unemployment Lack of job opportunities	New jobs		
	Rural development	Invest in farms and farm generation renewal	Economic diversification	Local rural development

[6] A. Bonfante, A. Impagliazzo, N. Fiorentino, G. Langella, M. Mori, and M. Fagnano, "Supporting local farming communities and crop production resilience to climate change through giant reed (Arundo donax L.) cultivation: An Italian case study," *Science of the Total Environment,* vol. 601, pp. 603-613, 2017.

5 S-LCA of biobased value chains selected in Magic

5.1 Goal and Scope

5.1.1 Goal

The aim of the S-LCA in Magic is to understand the potential social impacts of the understudy biobased value chains to farmers, value chain actors and the local community.

The goal of this part of the analysis is to investigate the social and socio-economic implications from the rehabilitation of marginal land to produce crops for biobased materials and energy applications and identify good and socially sustainable options. The results can be used firstly to understand the social implications of such value chains and secondly to identify possibilities for improvements.

The work adopted the attributional model, which models social impacts that are associated with the question of "how the product is being made". This has been regarded as the most relevant and fit to be combined with the Value Chain Analysis concept and used to assess the selected value chains.

5.1.2 Scope

Ten value chains have been selected for in-depth analysis within the sustainability assessment in the framework of an internal project workshop on selection of value chains and interlinkages (MS6.2 / MS18).

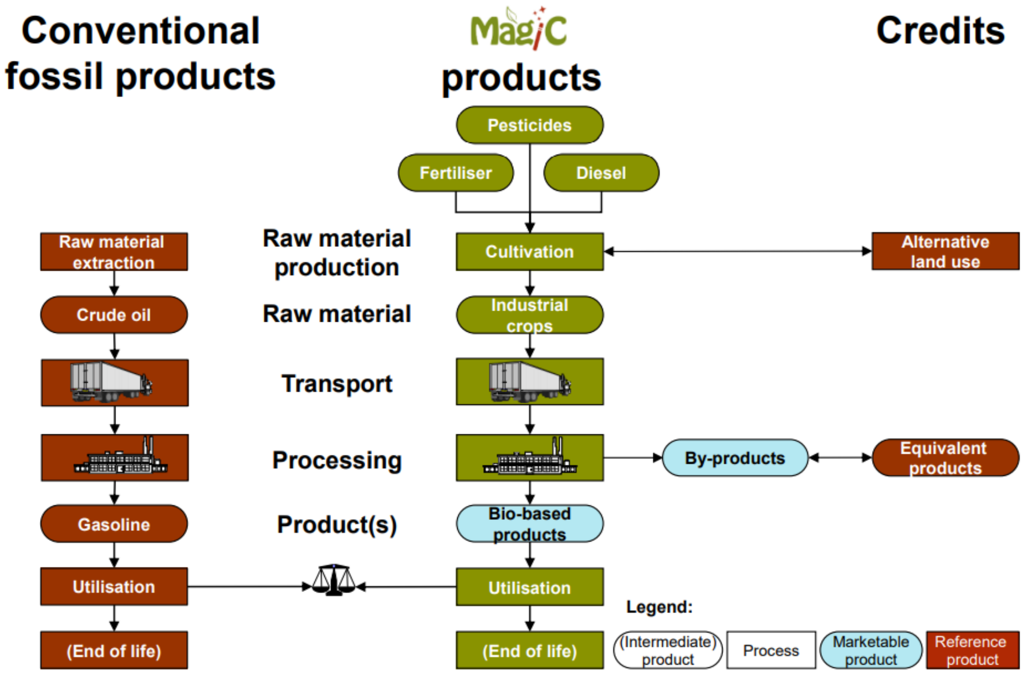

Figure 2 Sustainability assessment within the MAGIC project. The MAGIC bio-based products are compared to conventional reference products, both along the entire life cycle.

An overview of the ten selected value chains is given in Table 3. It shows a good representation of crops, conversion technologies and main products.

Table 2 Final selection of value chains for in-depth analysis within the sustainability assessment

Crop	Conversion technology	Main products[1]	Type
Miscanthus	Pyrolysis	Energy (industrial heat)	
Poplar	Gasification	Energy (SNG)	
Switchgrass	Fermentation	Ethanol	
Willow	Pyrolysis	Biochemicals (biotumen)	
Safflower (high oleic)	Oxidative cleavage	Azelaic and pelargonic acid	
Camelina (high oleic)	Metathesis	Methyl decenoate	
Castor	Alkaline cleavage	Sebacic acid	
Industrial hemp	Mechanical processing	Insulation material	
Sorghum	Anaerobic digestion	a) heat & power b) biomethane	
Lupin	Extraction	Adhesives	/

5.1.3 Functional Unit

The reference unit of 1 hectare of occupied land for 1 year for biomass production systems is applied within the MAGIC project. For RED-related analyses, the output-based reference unit of 1 MJ fuel is used as specified in the RED II.

5.1.4 Stakeholder categories

UNEP/SETAC includes the following stakeholder categories: local community, value chain actors, consumers, workers, and society. In Magic, we have included farmers (in the category of workers), value chain actors and local community. Their relevance to the value chain stages is illustrated in Figure 3 and described in this section below.

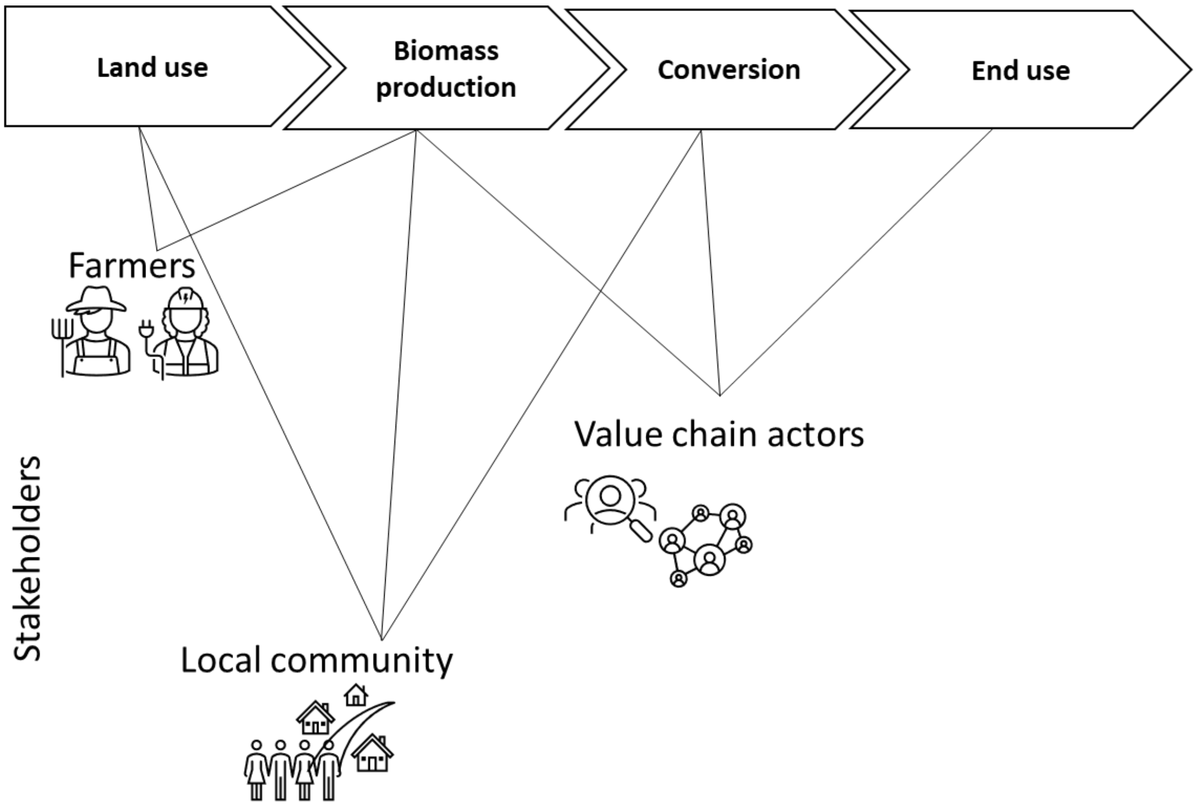

Figure 3 Stakeholder's relevance across value chain stages

Land use

- Farmers and local community can advise of future plausible options that are well integrated to current land use patterns.
- Farmers can take active interest in evaluating opportunities for marginal land.

Biomass production

- Farmers and value chain actors can adopt resource efficient practices in biomass production.
- Value chain actors should support the resource efficient biomass conversion to energy/ biobased products.
- Farmers, local community, and value chain actors can advise on policy relevant needs and guide targeted financial support.

Conversion

- Value chain actors and local community with the support from government should invest in knowledge distribution, capacity building.
- Value chain actors and local community with the support from government and funding institutions can provide financial support to industries and businesses to help the initial high investment cost of transition from fossil based to biomass-based technologies.

End Use

- Value chain actors and local community can adopt standards which can regulate the quality of biomass feedstock.
- Value chain actors and local community can implement labelling mechanisms which can help in the quality monitoring.
- Value chain actors and local community should contribute to increase the awareness of consumers and facilitate change in consumers' behaviour.

5.1.5 Indicators

tbc

Only indicators that are relevant for the specific value chain stages will be considered.

The indicators in Part A for the SLCA use the functional unit of 1ha/year whilst the analysis in Part B for countries uses the respective indicators from the SCP database so that we can have uniform data and evaluate opportunities- example if land use is reduced in Greece, this means that the biobased value chains offer an opportunity to improve land footprint per capita in a sustainable manner.

Table 3 Stakeholder and impact categories, indicators, and relevance to challenges within and across the value chain stages

Stakeholder category	Impact category	Category indicators	VC stage[7]	Inventory indicators	Relevance to value chain stages/ challenges
Farmers	Working conditions	Wages (diversification of income)	BP	Income and profitability per crop/ country-	Unemployment, Lack of job opportunities
		Social benefits	BP	Incentives at farm level (FF55 Fund, Just Transition Fund, CAP)	Social and economic resilience in rural areas
		Health and safety	BP		
Value chain actors	Innovation	Technology development	C	TRL	Advanced and efficient technologies are not supported enough.
		System versatility	C	Scale & relationship to logistics	Lack of awareness in SMEs and industries
		Market prospects	EU	Market size and trends	
Local community	Natural resources	Biodiversity	BP	Crop traits relevant to biodiversity	Safeguard planetary boundaries
		Land use and development	LU	Land occupancy (annual/ perennial)	Access to neglected natural resources
		Access to natural resources	LU	Crop yields/ha	Access to neglected natural resources
	Rural development	Local employment	All	Jobs	Unemployment, Lack of job opportunities
		Contribution to rural economy	All	Gross Value Added (GVA)	Rural development
	Governance	Public commitment to sustainability	All	Policies from S2Biom, literature, etc.	Low awareness of benefits and usability of biobased products

[7] Land Use (LU); Biomass Production (BP); Conversion (C); End Use (EU)

5.2 Inventory

tba

Data collection has been based on a combination of statistics, literature review, interviews, ….

Table 4 Stakeholder groups contacted during the Life Cycle Inventory and their relevance to the value chain stages.

Value chain stage	Stakeholders contacted	Number	Country
	Farmers		
	Value chain actors		
	Local community		

A few words about the crops that are not cultivated yet- only a few are commercial

The same about the technologies

Main limitation is the bias in data through the individual views of stakeholders as well as the fragmented nature of data

5.3 Impact assessment

This section provides the individual impact assessment for the understudy biobased value chains.

To assess the results, two types of characterisation models were chosen. The first one aggregates the qualitative data from the sub- and category indicators into impact categories by a summary of the social issues of each biobased value chain. The other characterisation model, a scoring system, is used to aggregate the data in a more quantitative and visual manner and to provide the possibility of comparison between them.

5.3.1 Qualitative assessment of the biobased value chain for the impact categories

Detailed process schemes can be found in the Annex to D 6.2 [Alexopoulou et al. 2020].

5.3.2 Scoring system

… a scoring system has been introduced where any social risks regarding each of the category indicators has been graded for each stage. The results are represented in table 6, where negative social effects result in a higher score.

Low risk	-3
Medium risk	-1
High risk	1
Very High risk	3

Figure 4 Scoring system for social risks

EXPLAIN briefly why these scores…

Table 5 Scoring of risks from the understudy value chains per stage of operation

Value chains	Land use	Biomass production	Conversion	End use	Horizontal
Miscanthus, Pyrolysis, Industrial Heat	1	-1	-3	-1	-1
SNG from poplar (via gasification)	1	-1	-1	-1	-1
Ethanol from switchgrass (via hydrolysis & fermentation)	1	-1	-3	-3	-1
Biotumen from willow (via pyrolysis)	1	-1	-1	-3	-1
Organic acids from safflower	-3	-3	-1	-1	-3
Methyl decenoate from camelina	-3	-3	-1	-1	-3
Sebacic acid from castor oil	-3	-3	-1	-1	-3
Insulation material from hemp	-1	-3	-3	-3	-3
Biogas/biomethane from sorghum	-1	-3	-3	-1	-1
Adhesives from lupin	-3	-3	-1	-3	-3

tbc

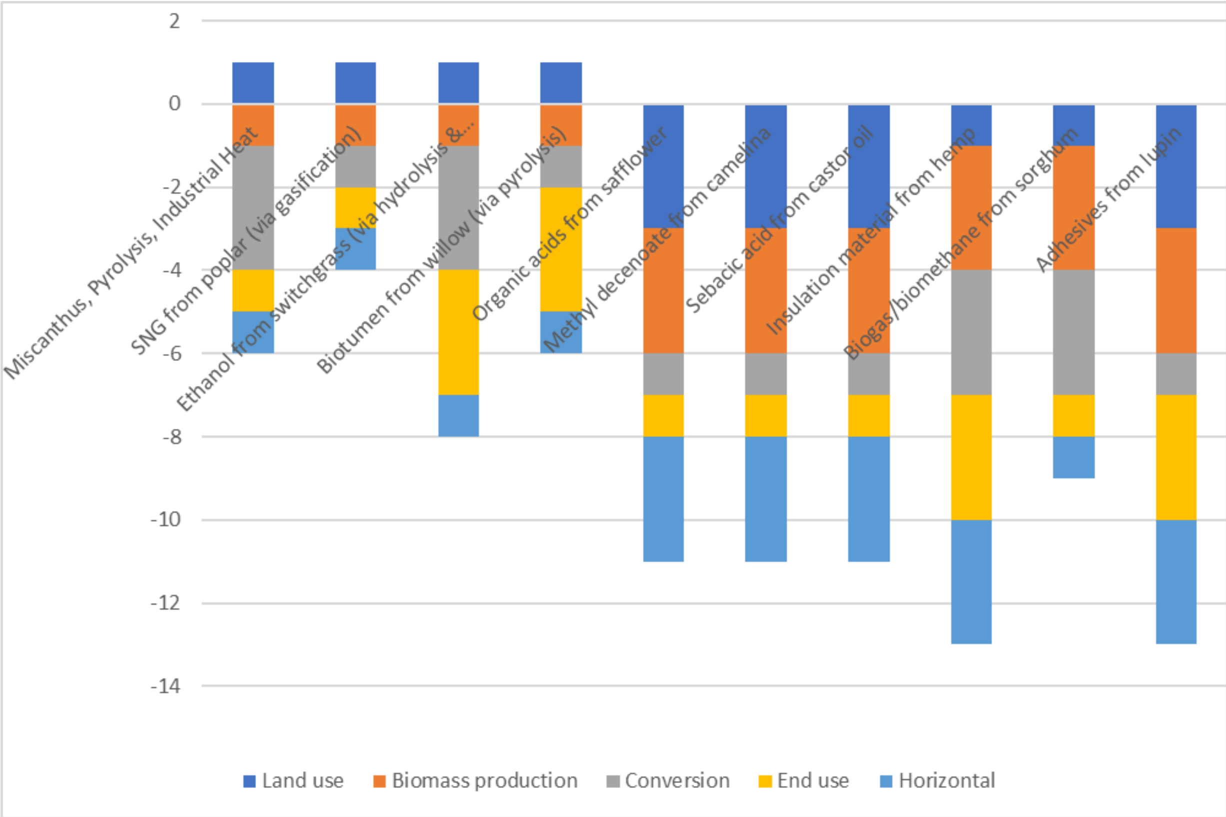

Figure 5 Overall scoring of risks within value chain stages in the understudy biobased value chains

5.3.3 Value chain assessment

5.3.3.1 VC 1: Industrial heat from Miscanthus (via pyrolysis)

This value chain describes the conversion of Miscanthus (Miscanthus x giganteus) to pyrolysis oil, which is then used to produce industrial heat. This life cycle is compared to conventional ways of providing the same products or services (Figure 6).

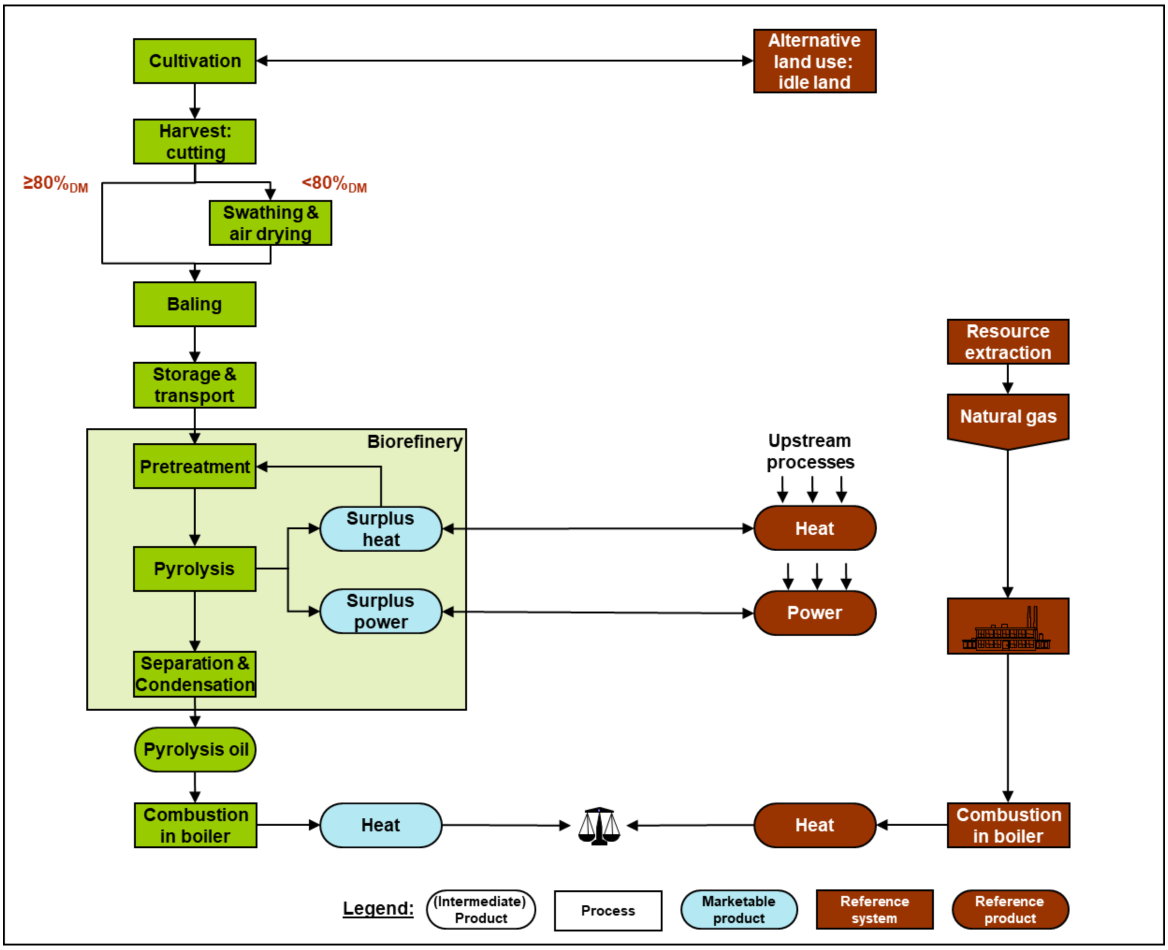

Figure 6 Simplified life cycle comparison for VC 1: industrial heat from Miscanthus via pyrolysis versus industrial heat from fossil energy carriers.

Working conditions (Income diversification, social benefits, health and safety)

Miscanthus is a perennial grass that can be cultivated at low input systems across Europe. The crop propagates via rhizomes, and often reaches a maximum height of 3–3.5 m[8]. It has low nutritional requirements and high nitrogen use efficiency and therefore can grow well on

[8] Lewandowski, I.; Clifton-Brown, J.; Scurlock, J.; Huisman, W. Miscanthus: European experience with a novel energy crop. Biomass Bioenergy 2000, 19, 210

marginal land with relatively low inputs of fertiliser[9]. As a perennial plantation it offers opportunities for income diversification for farmers and landowners. Harvesting times vary, depending on climate but on most occasions, they can complement farm efforts throughout the year when the traditional crops are cereals.

Innovation (Technology development, System versatility, Market prospects)

Pyrolysis is an innovative conversion pathway with Technological Readiness Level 6-7. The major advantages of pyrolysis oil include its storability, high energy density compared to raw biomass, and flexibility with respect to downstream processing and use options[10]. There are several studies for pyrolysis of Miscanthus, which show these are suitable feedstocks for this process[11] [12]. A total efficiency of 90% can be achieved with modern systems. Pyrolysis oil can be stored and transported over longer distances (in comparison to the untreated feedstock). The potential market size can be limited by industrial heat demand, and by the presence of district heating.

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Perennial, non-food crops such as Miscanthus are considered a resource efficient option for European countries since they are established once, have dense rooting systems, use low water and nutrient inputs and have high drought resistance. Land use change is considered limited in case of marginal lands which are not suited for arable crops requiring higher quality soils. Perennial cropping reduces tillage and erosion risks[13] and increases soil carbon. Compared to arable crops, miscanthus exhibits low GHG emissions, reduces flood risk and nitrate leaching (Lewandowski et al., 2016), increases soil carbon sequestration and improves biodiversity (Bellamy et al., 2009).[14] Use of pesticides other than herbicides and chemical fertilisers are not recommended. As the site is only cultivated once, at establishment, reductions in soil disturbance and erosion can also be achieved compared with conventional arable crops[15].

[9] Lesur, C.; Jeuffroy, M.H.; Makowski, D.; Riche, A.B.; Shield, I.; Yates, N.; Fritz, M.; Formowitz, B.; Grunert, M.; Jorgensen, U.; et al. Modeling long-term yield trends of Miscanthus × giganteus using experimental data from across Europe. Field Crops Res. 2013, 149, 252–260.
[10] Bridgwater, A.V. Biomass Pyrolysis. IEA Bioenergy, October 2010. Available online: http://www.ieabioenergy.com/ wp-content/uploads/2013/10/ExCo66-P2-Biomass-pyrolysis-Tony-Bridgwater1.pdf
[11] Mos, M.; Banks, S.W.; Nowakowski, D.J.; Robson, P.R.H.; Bridgwater, A.V.; Donnison, I.S. Impact of Miscanthus × Giganteus senescence times on fast pyrolysis bio-oil quality. Bioresour. Technol. 2013, 129, 335–342.
[12] Mimmo, T.; Panzacchi, P.; Baratieri, M.; Davies, C.A.; Tonon, G. Effect of pyrolysis temperature on Miscanthus (Miscanthus × Giganteus) biochar physical, chemical and functional properties. Biomass Bioenergy 2014, 62, 149–157.
[13] The Land Institute. Perennial Grain Cropping Research: Why Perennial Grain Crops? Perennial Grain Cropping Research: Why Perennial Grain Crops? 2016. Available online: https://landinstitute.org/our-work/ perennial-crops/
[14] Bellamy, P. E., Croxton, P. J., Heard, M. S., Hinsley, S. A., Hulmes, L., Hulmes, S., et al. (2009). The impact of growing miscanthus for biomass on farmland bird populations. *Biomass Bioenergy* 33, 191–199. doi: 10.1016/j.biombioe.2008.07.001
[15] https://www.forestresearch.gov.uk/documents/2055/FR_BEC_Planting_and_growing_Miscanthus_2007.pdf

Rural development (Local employment, Contribution to rural economy)

Perennial crops, like miscanthus, offer significant opportunities for income diversification[16] and are attractive options for low quality land which remains unused or is abandoned due to low profitability prospects.

Governance (Public commitment to sustainability)

Cultivation of Miscanthus using low quality, marginal land and using it for industrial heat fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Clean energy: Clean energy
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Climate action: Making the EU climate neutral by 2050

[16] Panoutsou, C. Socio-economic impacts of energy crops for heat generation in Northern Greece. Energy Policy 2007, 35, 6046–6059.

Figure 7 illustrates a comparison of the value chain for marginal and conventional land.

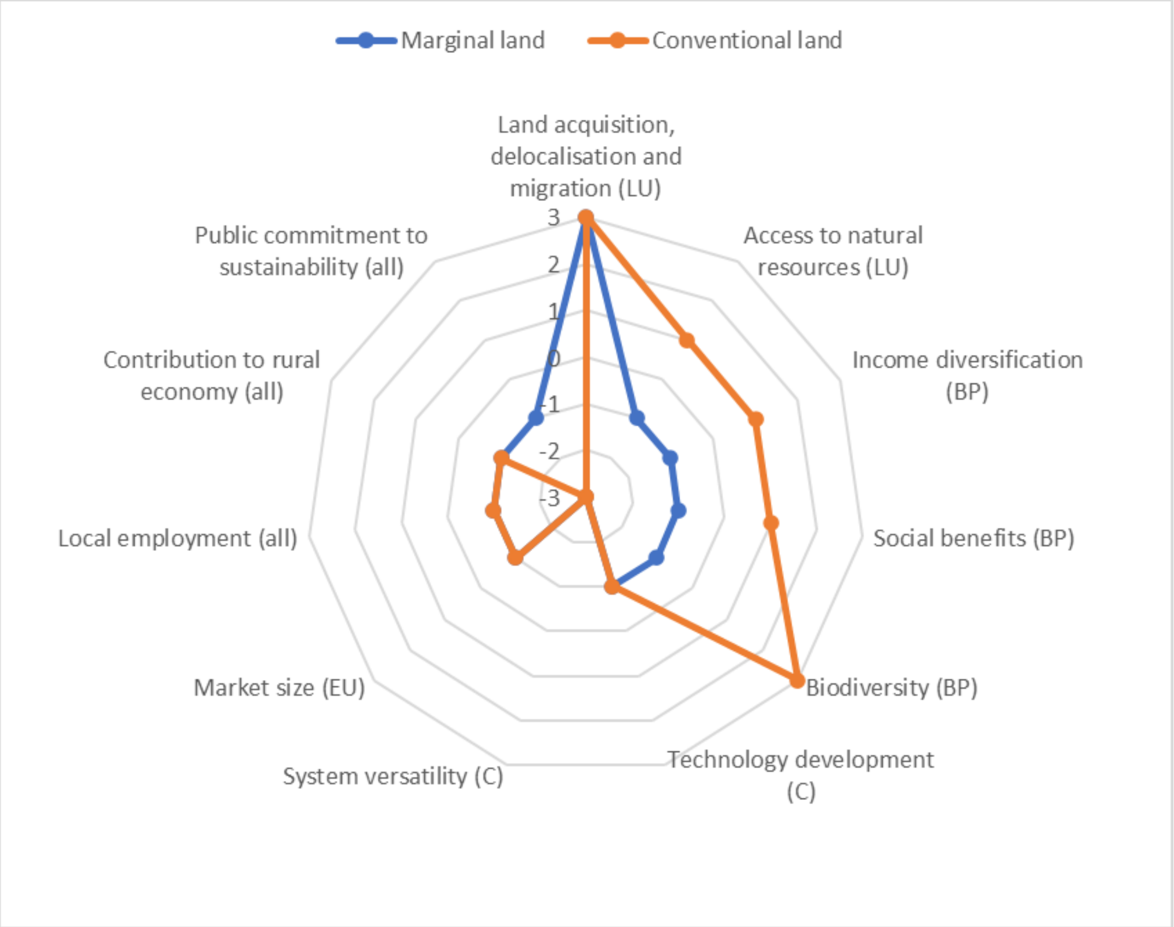

Figure 7 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. This scoring is primarily due to the fact that miscanthus is a non-food crop of perennial nature which entails risks for competition with food and feed cropping and also long-term commitment for land use. Miscanthus can be a good option for marginal land, but it is considered of very high social risk for conventional arable land in terms of biodiversity and high risk for access to natural resources and income diversification for competition with other food and feed crops.

tbc

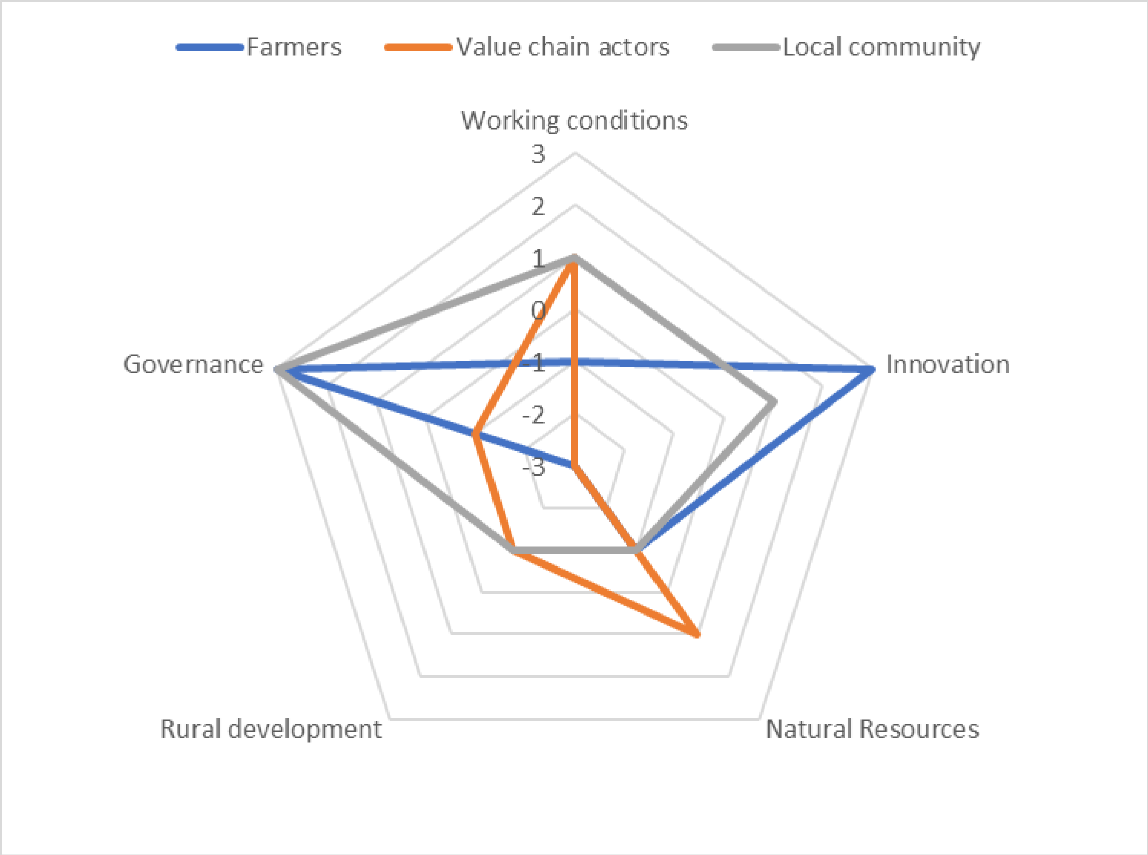

Figure 8 risk scoring for the impact categories from the three stakeholder groups

Figure 8 illustrates risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.2 VC 2: SNG from poplar (via gasification)

This value chain describes the production of synthetic natural gas (SNG) from poplar (Populus spp. L.) by gasification. This life cycle is compared to conventional ways of providing the same products or services (Figure 9).

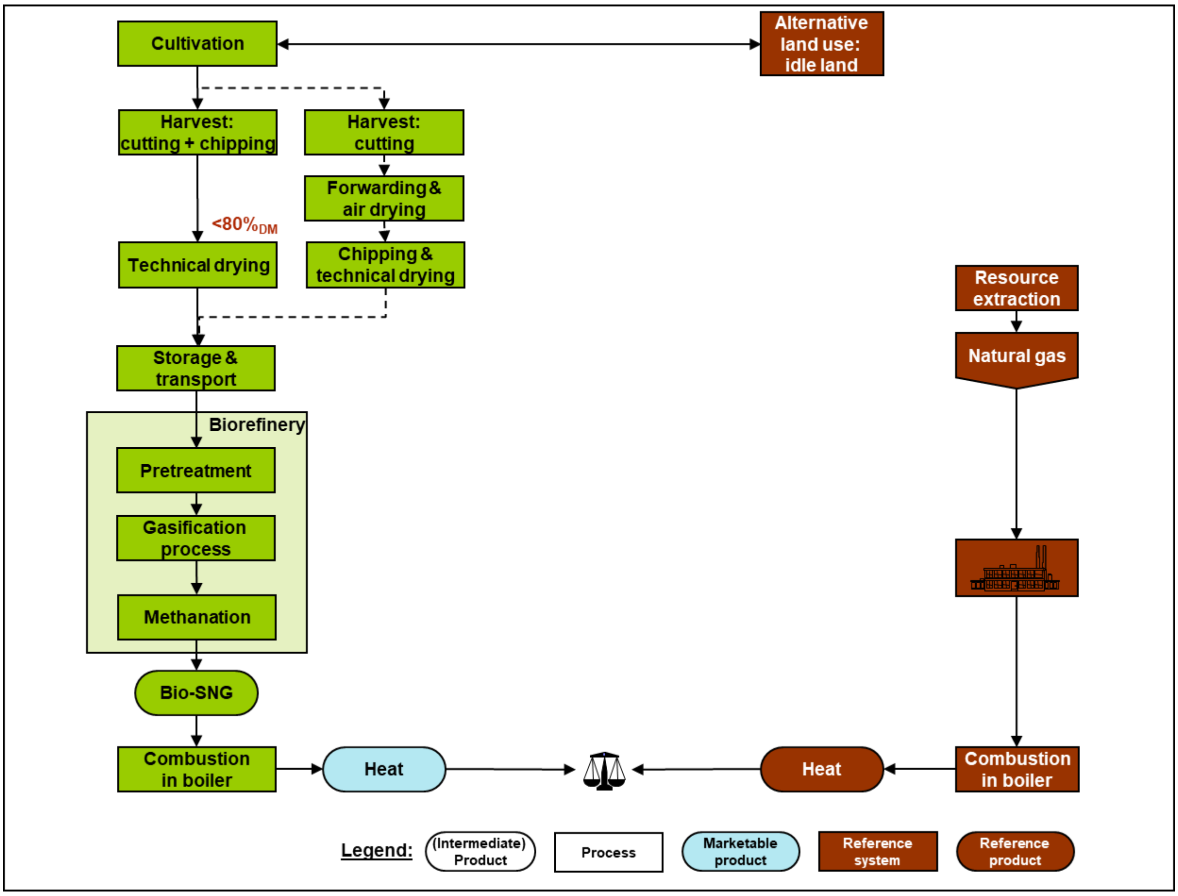

Figure 9 Simplified life cycle comparison for VC 2: synthetic natural gas from poplar via gasification versus natural gas.

Working conditions (Income diversification, social benefits, health and safety)

Poplar is a perennial C3-crop, usually planted for pulpwood production in various countries. The typical rotation times range from 3-4 years for coppice systems or 8–10 years for single stem systems. Short Rotation Coppice, such as poplar, can offer significant opportunities for income diversification and are attractive options for low quality land which remains unused or is abandoned due to low profitability prospects. They can also be planted as hedge crops and in public areas, such as roads, parks, etc.

Innovation (Technology development, System versatility, Market prospects)

Gasification is an innovative conversion pathway. Implementation requires additional investments and if not directly combusted an intensive gas cleaning step (tar removal, etc.) is necessary. Via this route synthetic natural gas can benefit from all the advantages of natural gas, like the existing dense infrastructure, trade and supply network, and natural gas applications[17].
When SNG is used for medium scale, heat driven CHP it can capture an important market for industrial and commercial heat. Conversion efficiency can reach up to 80%, depending on heat only or CHP installations.

Natural resources (Biodiversity, Land use and development, Access to natural resources)

As a perennial crop poplar requires low pesticide and nitrogen applications so (practically) no direct negative impacts on habitat quality; can provide winter shelter and birds nesting inside plants. Poplars can reduce soil erosion and desertification, increase biodiversity of natural habitats, and enhance the landscape. They can also be planted as buffer strips in cultivated lands near waterways to promote nitrate absorption and prevent water eutrophication[18]. Demonstration results from the SEEMLA project in Germany have shown that poplar is suitable for being grown on marginal land, especially on post-mining sites and areas with very poor soil quality[19] and used for land reclamation purposes and as bioenergy crops.

Rural development (Local employment, Contribution to rural economy)

Perennial plantations, like poplar, offer significant opportunities to rehabilitate low quality land which remains unused or is abandoned due to low profitability prospects. Poplar can be cultivated as part of agroforestry systems and as such it can also offer significant opportunities for local employment and contribute to rural economy.

Governance (Public commitment to sustainability)

Cultivation of poplar using low quality, marginal land and using it for medium scale heat fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Clean energy: Clean energy
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Eliminating pollution: Measures to cut pollution rapidly and efficiently

[17] https://www.biosng.com/fileadmin/biosng/user/documents/reports/e06018.pdf
[18] http://brivioplywood.com/en/poplar/environment-protection
[19] https://www.seemla.eu/home/

- Climate action: Making the EU climate neutral by 2050

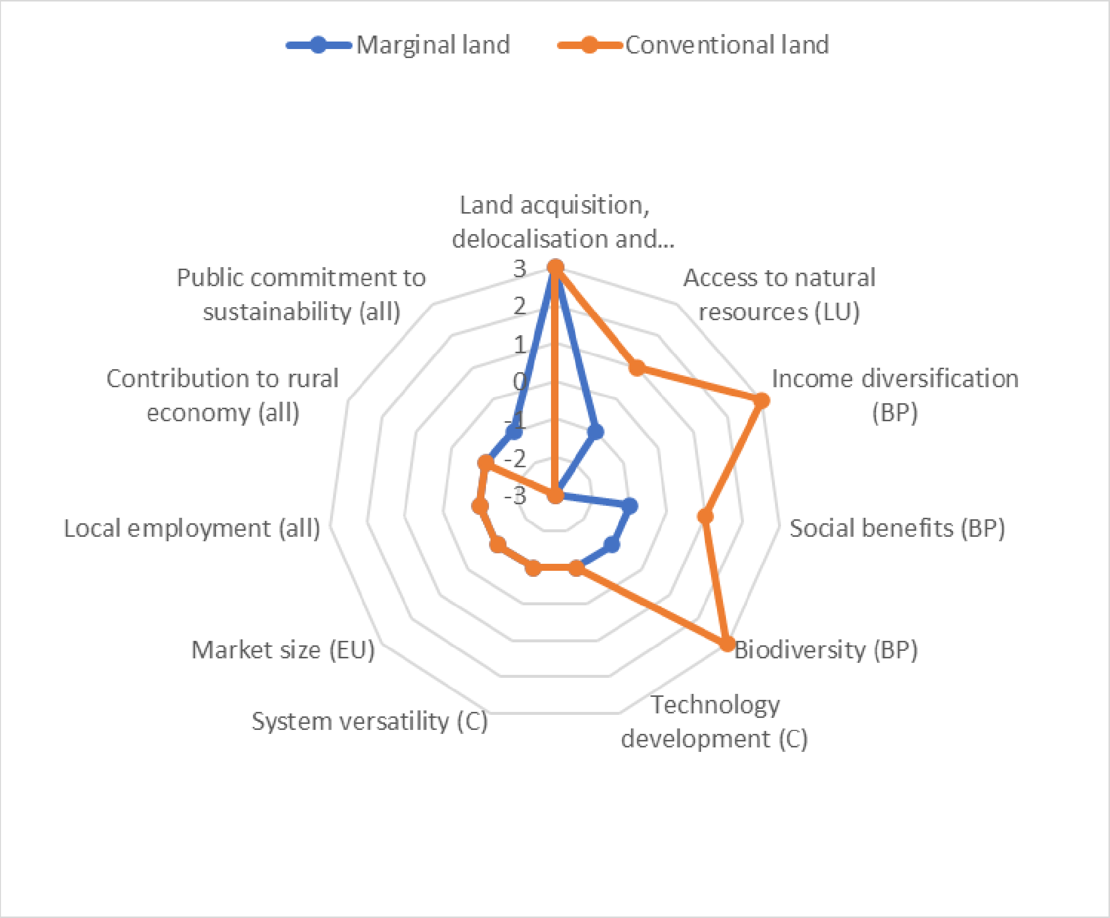

Figure 10 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 10 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Poplar can be a good option for marginal land, but it is considered of very high social risk for conventional arable land in terms of biodiversity and income diversification due to the fast growing and perennial nature of the crop and high risk for access to natural resources for competition with other food and feed crops. The latter can be compensated if poplar is cultivated as part of agroforestry systems.

tbc

Figure 11 illustrates risk scoring for the impact categories from the three stakeholder groups

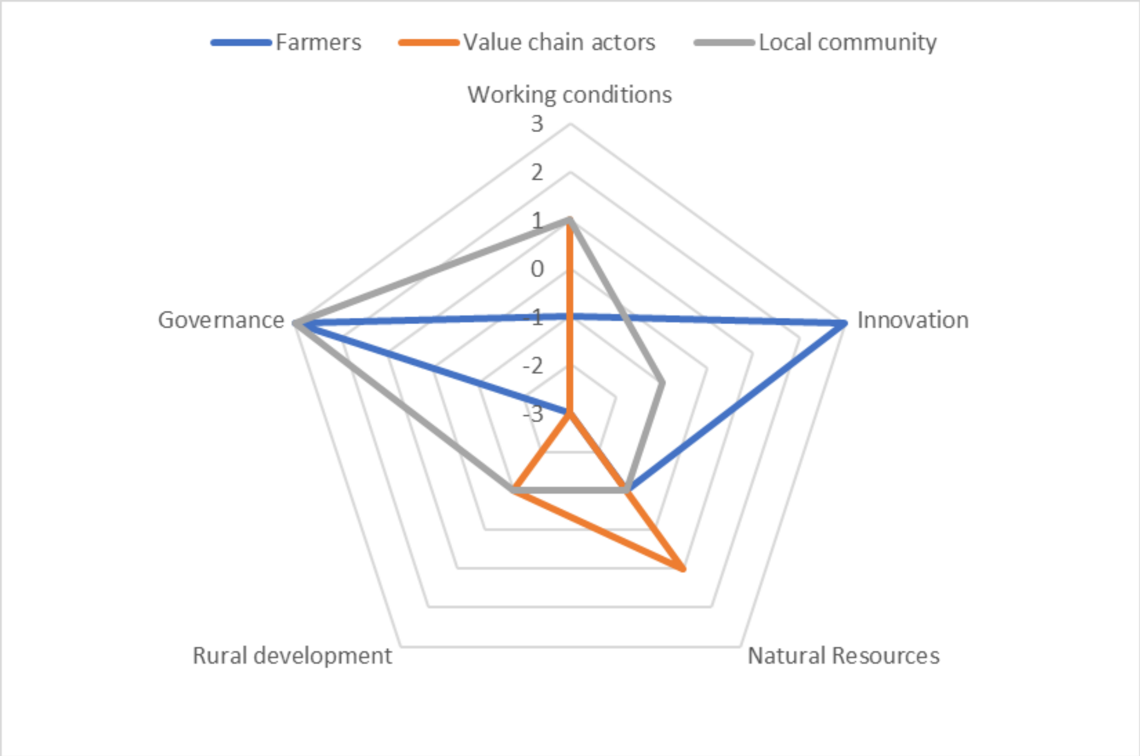

Figure 11 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.3 VC 3: Ethanol from switchgrass (via hydrolysis & fermentation)

This value chain describes the conversion of switchgrass (Panicum virgatum L.) to ethanol via hydrolysis and fermentation. This life cycle is compared to conventional ways of providing the same products or services (Figure 12).

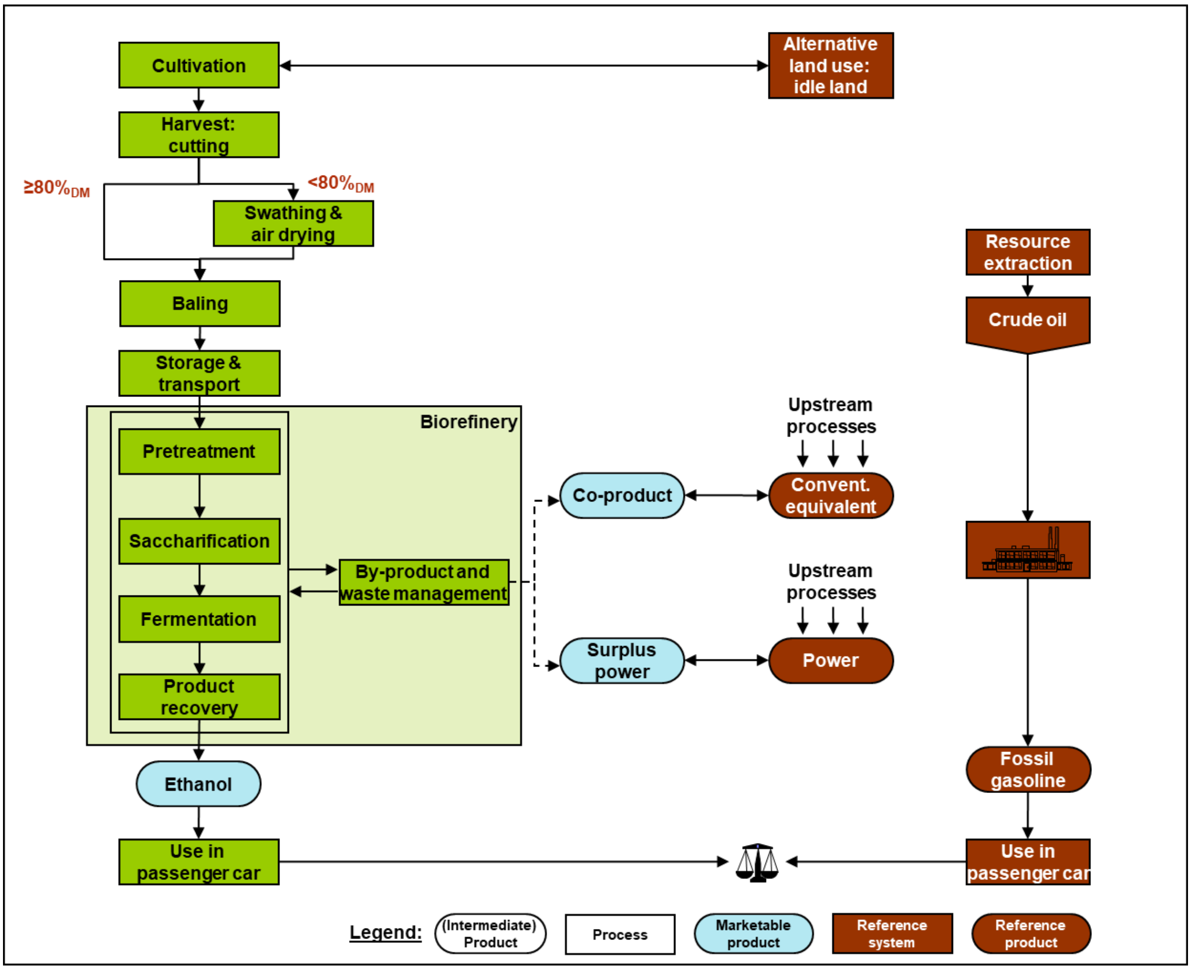

Figure 12 Simplified life cycle comparison for VC 3: ethanol from switchgrass via hydrolysis and fermentation versus fossil gasoline.

Working conditions (Income diversification, social benefits, health and safety)

Switchgrass is a perennial herbaceous C4 warm season grass native to Northern America. The crop can reach up to 3 m height, and is suitable for bioenergy, biofuels and biobased materials. As a perennial grass it can also be used as cover crop for soil conservation.

Innovation (Technology development, System versatility, Market prospects)

The technology is at pre-commercial stage. Ethanol is mostly focused at passenger cars, where electric propulsion can have an important role. The value chain is more efficient when it is integrated with existing ethanol facilities. Biomass input does not need to be dry (in contrast with the thermochemical processes).

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Switchgrass has good adaptability to a wide range of climates and marginal soils. It is tolerant to drought and can have high productivity in drought conditions. Herbicides are required for weed control only during the establishment. The crop has high water use efficiency and moderate nutrient requirements during the 2nd year of establishment. It is also considered a good crop option for soil remediation and phytoextraction.

Rural development (Local employment, Contribution to rural economy)

Perennial crops, like switchgrass, offer significant opportunities for income diversification and are attractive options for low quality land which remains unused or is abandoned due to low profitability prospects.

Governance (Public commitment to sustainability)

Cultivation of switchgrass using low quality, marginal land and using it for ethanol fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Clean energy: Clean energy
- Sustainable mobility: Promoting more sustainable means of transport
- Eliminating pollution: Measures to cut pollution rapidly and efficiently

Figure 13 illustrates a comparison of the value chain for marginal and conventional land.

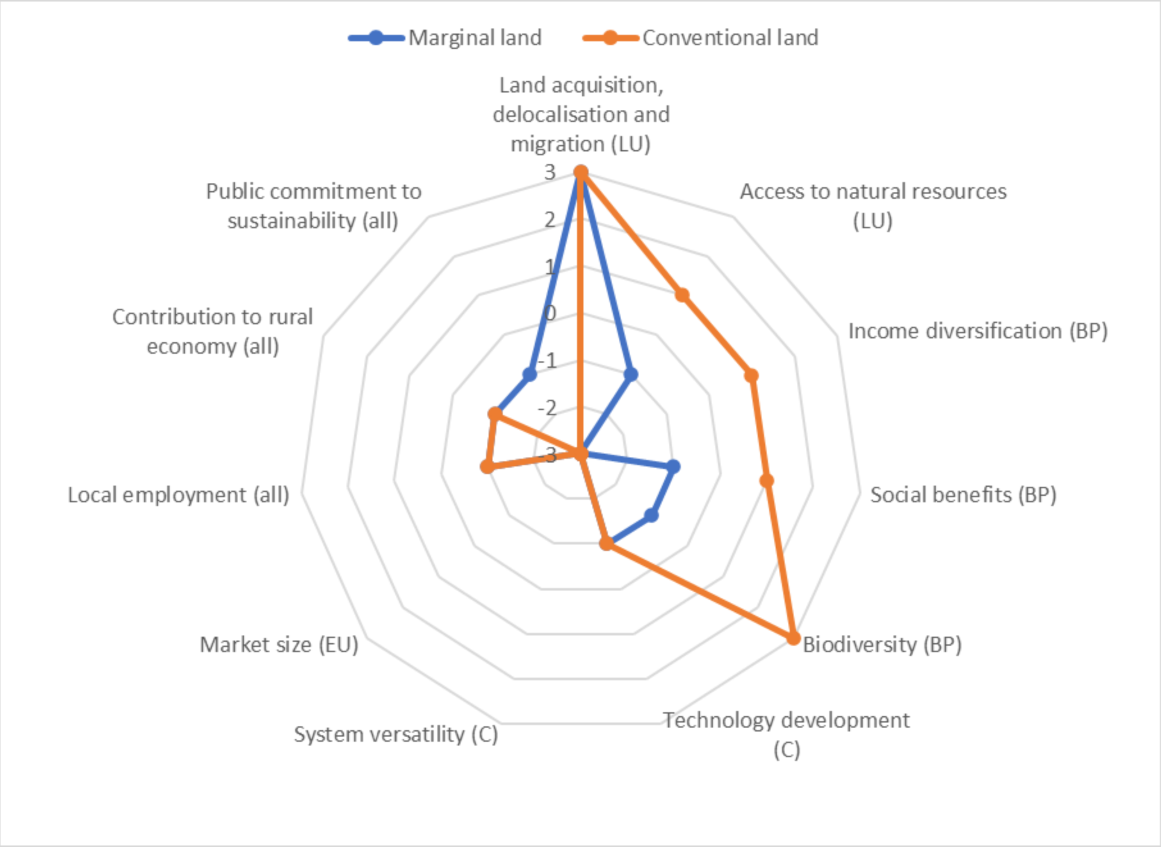

Figure 13 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Switchgrass can be a good option form marginal land, but it is considered of very high social risk for conventional arable land in terms of biodiversity and high risk for access to natural resources and income diversification for competition with other food and feed crops.

tbc

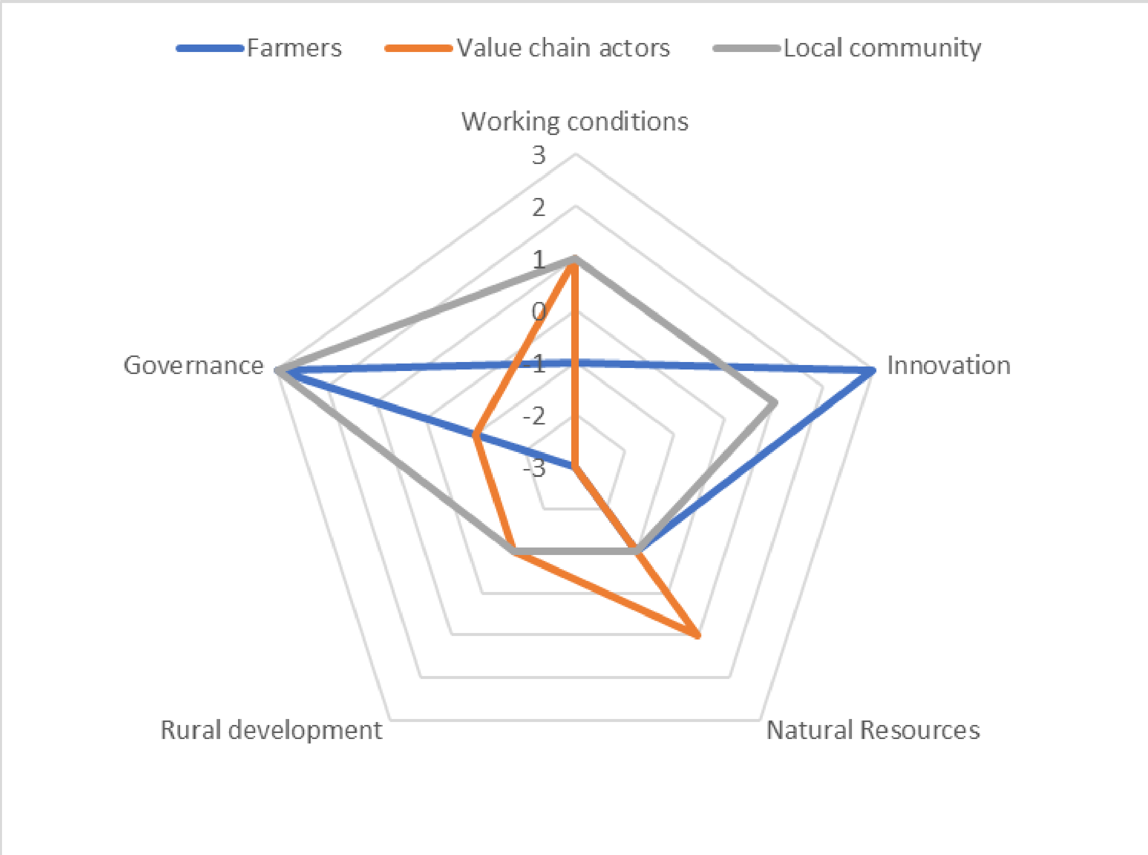

Figure 14 risk scoring for the impact categories from the three stakeholder groups

Figure 14 illustrates risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.4 VC 4: Biotumen from willow (via pyrolysis)

This value chain describes the conversion of willow (Salix spp. L.) by pyrolysis to form biotumen, which can replace fossil-based bitumen in roofing material. This life cycle is compared to conventional ways of providing the same products or services (Figure 15).

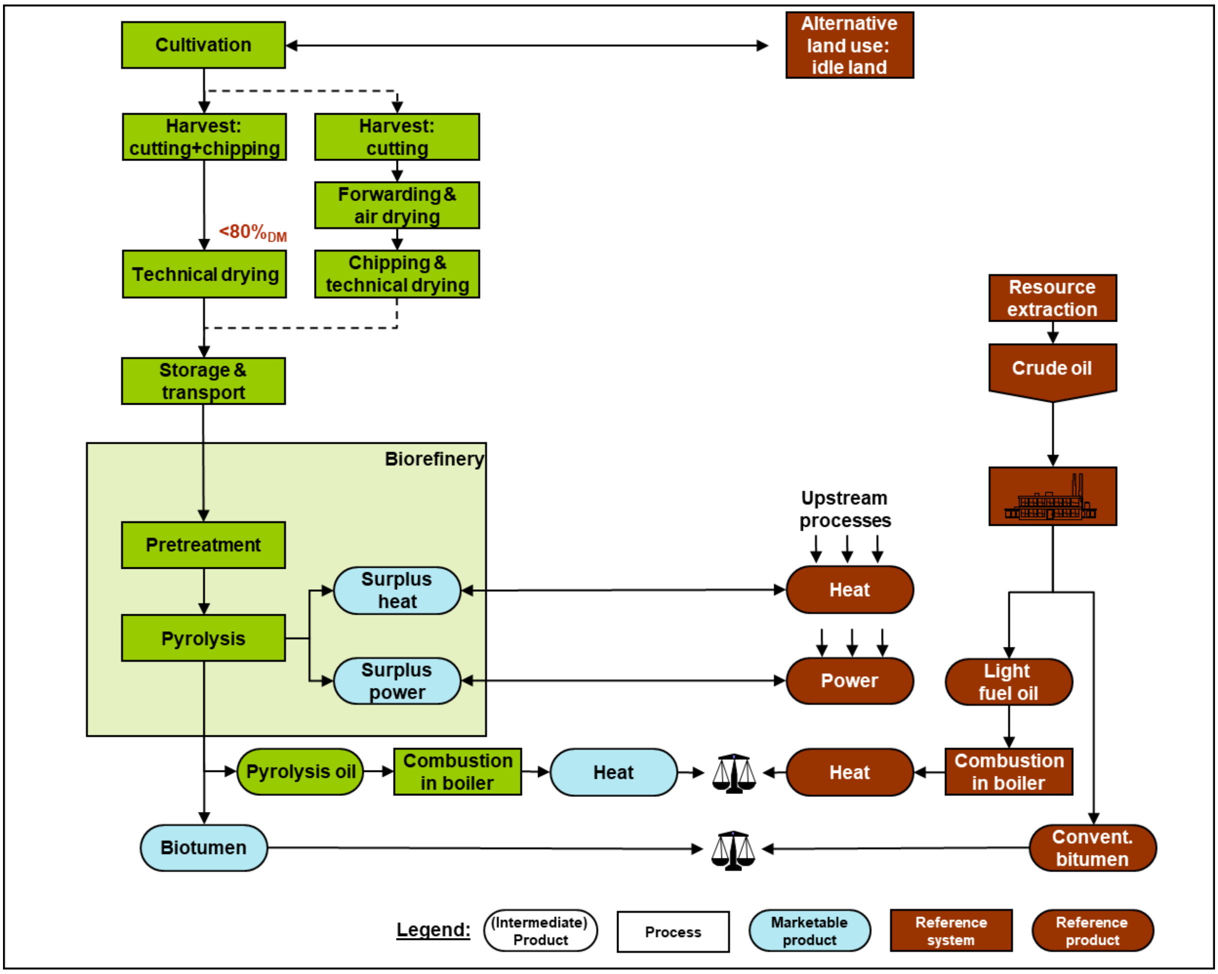

Figure 15 Simplified life cycle comparison for VC 4: biotumen from willow via pyrolysis versus bitumen from fossil resources.

Working conditions (Income diversification, social benefits, health and safety)

Willows[20] are fast growing large trees or shrubs, with height from 13.7 to 21 m. It is usually grown for biomass or biofuel, in energy forestry systems, as a consequence of its high energy in-energy out ratio, large carbon mitigation potential and fast growth, is used for biofiltration,

[20] Factsheet on Weeping Willow, Edward F. Gilman and Dennis G. Watso1994 http://hort.ufl.edu/trees/SALSPPA.pdf

constructed wetlands, ecological wastewater treatment systems, hedges, land reclamation, landscaping, phytoremediation, soil erosion control, shelterbelt and windbreak and also soil reclamation. Short Rotation Coppice, such as willow, can offer significant opportunities for income diversification and are attractive options for low quality land which remains unused or is abandoned due to low profitability prospects. They can also be planted as hedge crops and in public areas, such as roads, parks, etc.

Innovation (Technology development, System versatility, Market prospects)

Biotumen from willow can replace the fossil-based bitumen. Bitumen (or asphalt), is a substance known for its waterproofing and adhesive properties, can occur naturally or be formed through the distillation of crude oil. The technology is ***
Market prospects for biotumen are very good as it can have a high share in the respective building materials' sectors (roofing products, etc.) as well as road construction..
Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Willow is native to central and south Europe but can be adapted all over Europe. As a perennial crop the plantations require low pesticide and nitrogen applications so (practically) no direct negative impacts on habitat quality. It can provide winter shelter and birds nesting inside plants. It is tolerant to several soil types like acid and alkaline, clay, wet soils which occasionally flood and poor drainage soils. It is susceptible to stress (like drought conditions, ice, windstorm damage) and pests and diseases (like cankers, powdery mildew, leaf spots, willow leaf beetle, and scale). The crop has high canopy which has the benefit of altering the humidity and temperature of crops therefore improving the water use efficiency. Willow can increase carbon sequestration. The crop is suitable for soil remediation and land conservation practices be-cause it can be used for shelter-belt, windbreak and prevent soil erosion[21]. It can also be used for biofiltration, constructed wet-land, wastewater treatment systems.

Rural development (Local employment, Contribution to rural economy)

Perennial plantations, like willow, offer significant opportunities for income diversification and are attractive options for low quality land which remains unused or is abandoned due to low profitability prospects.

Governance (Public commitment to sustainability)

Cultivation of willow using low quality, marginal land and using it for biotumen fits well to certain policy areas and instruments in the European Green Deal. These include:

[21] Fernando AL, Costa J, Barbosa B, Monti A, Rettenmaier NJB, Bioenergy. Environmental impact assessment of perennial crops cultivation on marginal soils in the Mediterranean Region. 2018;111:174-86.

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Building and renovating: The need for a cleaner construction sector
- Climate action: Making the EU climate neutral by 2050

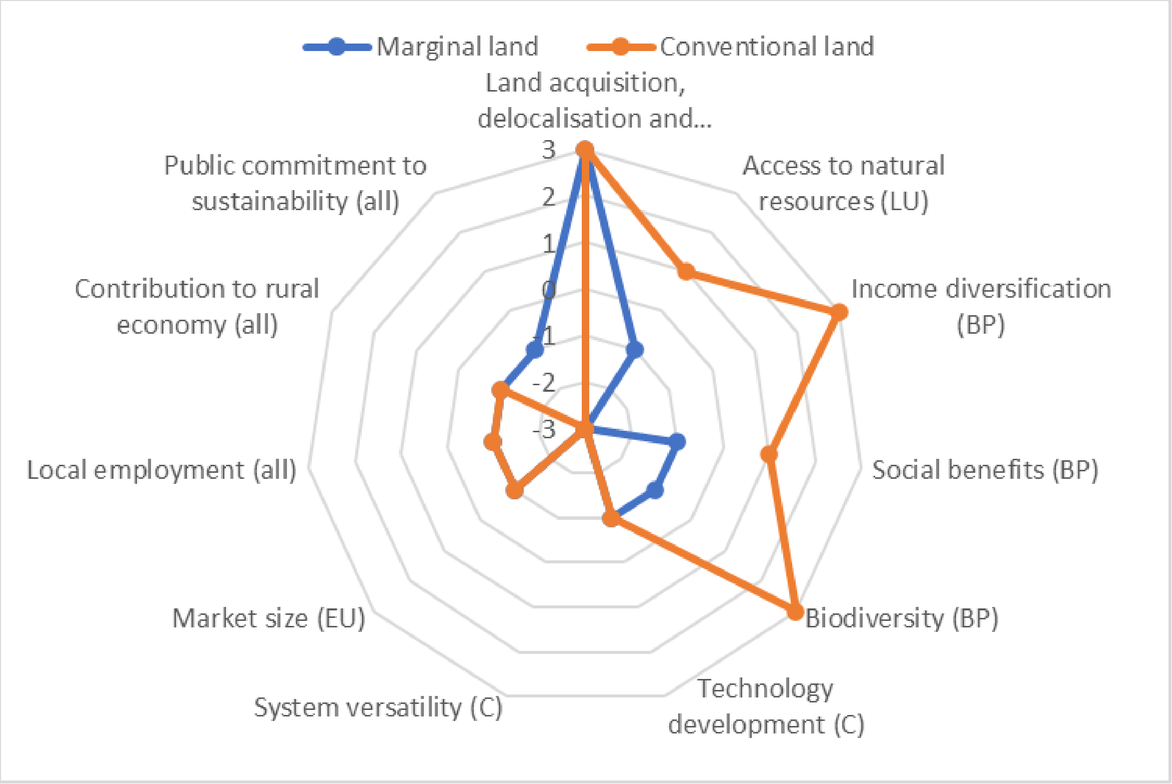

Figure 16 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 16 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Willow can be a good option form marginal land, but it is considered of very high social risk for conventional arable land in terms of biodiversity and high risk for access to natural resources and income diversification for competition with other food and feed crops.

Tbc

Figure 17 illustrates risk scoring for the impact categories from the three stakeholder groups

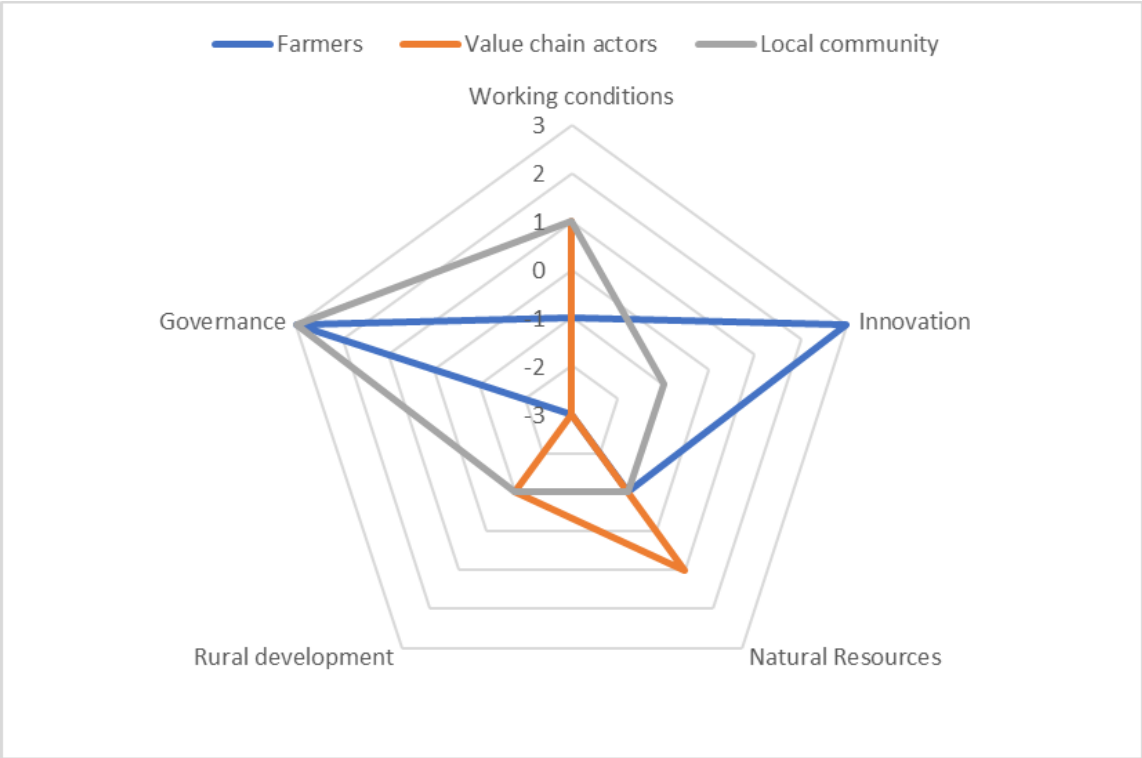

Figure 17 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.5 VC 5: Organic acids from safflower (via oxidative cleavage)

This value chain describes the conversion of a high-oleic safflower variety (Carthamus tinctorius L.) by oxidative cleavage to form organic acids. This life cycle is compared to conventional ways of providing the same products or services (Figure 18).

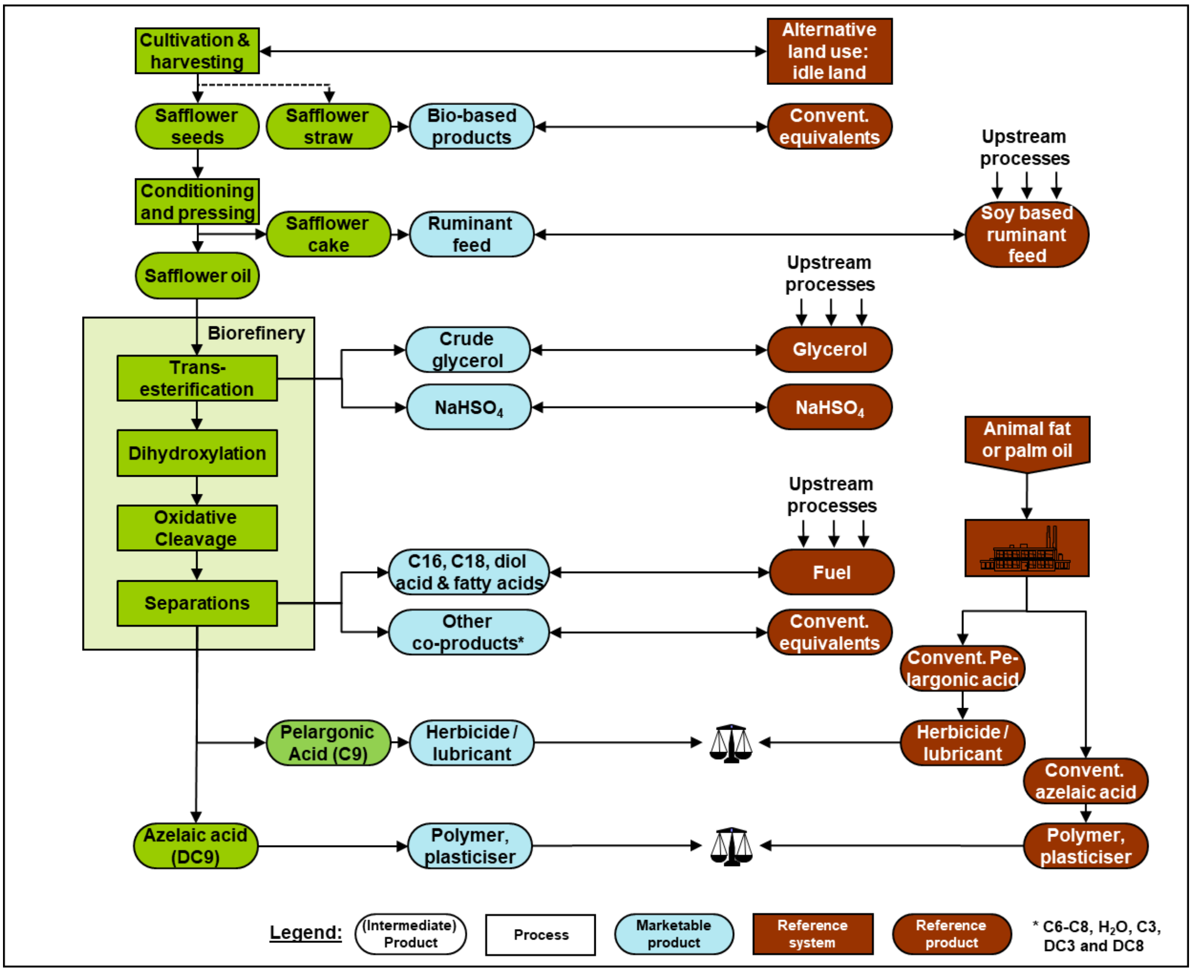

Figure 18 Simplified life cycle comparison for VC 5: organic acids from safflower via oxidative cleavage versus organic acids from fossil resources.

Working conditions (Income diversification, social benefits, health and safety)

Safflower is a branching thistle-like herbaceous annual (spring or winter) annual plant with numerous spines on leaves and bracts. It is best fits to South Europe and recently it has proposed as a promising oilseed crops for marginal lands.[22] Traditionally, safflower was cultivated for its seeds and used to flavour foods, colour textiles and medicines. There two

1. MAGIC Project, www.magic-h2020.eu

groups of varieties; the high oleic and the high linoleic. Recently, there is an increasing demand for high-oleic varieties as sources for several high-added value applications. The seeds meal that due to the high protein content (24%) it could be used as animal feed.

Innovation (Technology development, System versatility, Market prospects)

Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Safflower can be adapted very well to South Europe with very good yields. It is drought and high temperature tolerant, therefore can be grown without irrigation even on dry agroecological conditions. It can be grown on marginal lands and/or lands with heavy metals. The crop has no special needs for pesticides / herbicides. It has a tap rooting system that can use remaining nutrients in the soil from previous crops.

Rural development (Local employment, Contribution to rural economy)

Safflower can be integrated in crop rotations and offer significant opportunities for income diversification in arid areas which are at risk of desertification, especially in the Mediterranean agroecological zone. The crop has several market opportunities for pharmaceutical and medicinal uses: oil from the seeds has been used in skin and hair care products due to its moisturising properties. It contains high levels of naturally occurring lipids that nourish and smooth hair cuticles, promote hair growth, and hydrate the scalp. It is also used for diabetes, cardiovascular conditions, and cancer[23].
The crop gives farmers some options in a dryland crop rotation with respect to weed and disease control, and in using soil moisture available to its deep taproot. It is usually grown in rotation with small grains or fallow[24].

Governance (Public commitment to sustainability)

Cultivation of safflower using low quality, marginal land and using it for organic acids fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally-respectful production cycles
- Climate action: Making the EU climate neutral by 2050

[23] www.drugs.com › npp › safflower
[24] www.hort.purdue.edu/newcrop/afcm/safflower.html

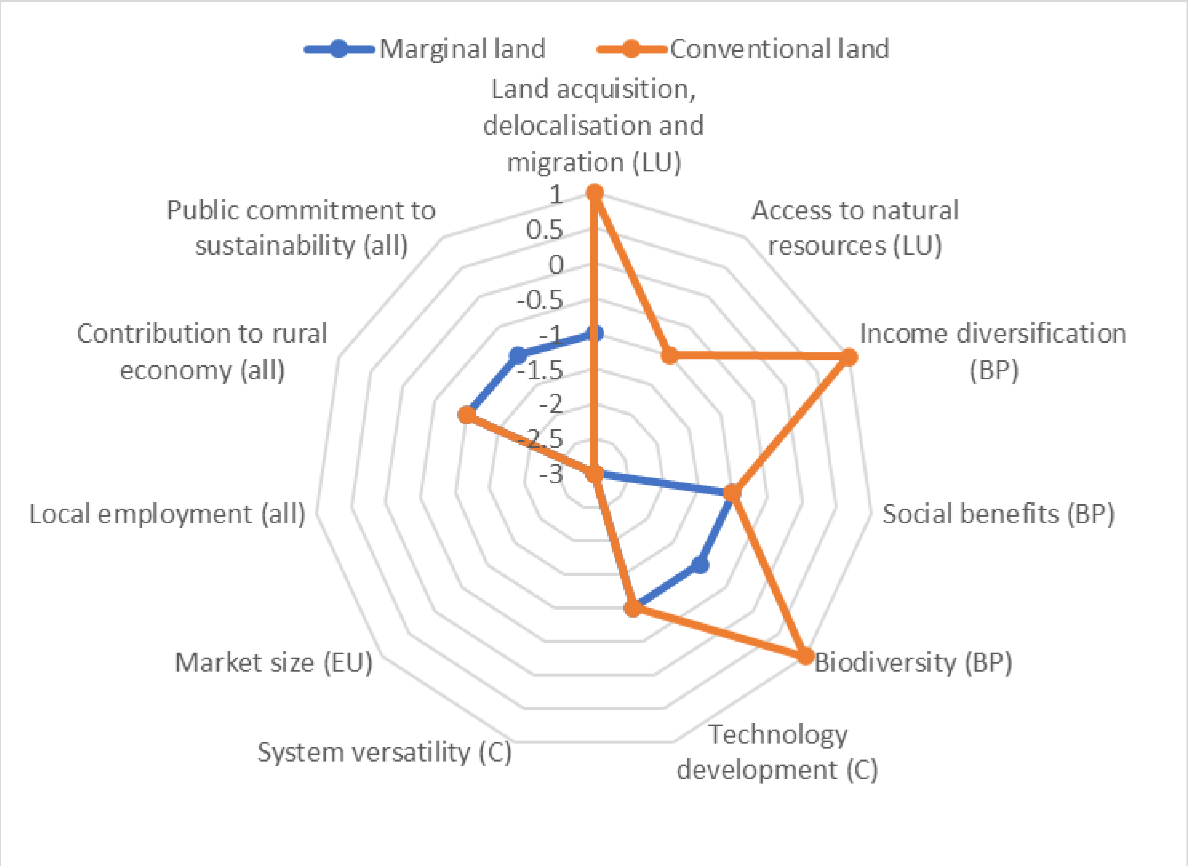

Figure 19 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 19 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Safflower can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems.

tbc

Figure 20 illustrates risk scoring for the impact categories from the three stakeholder groups

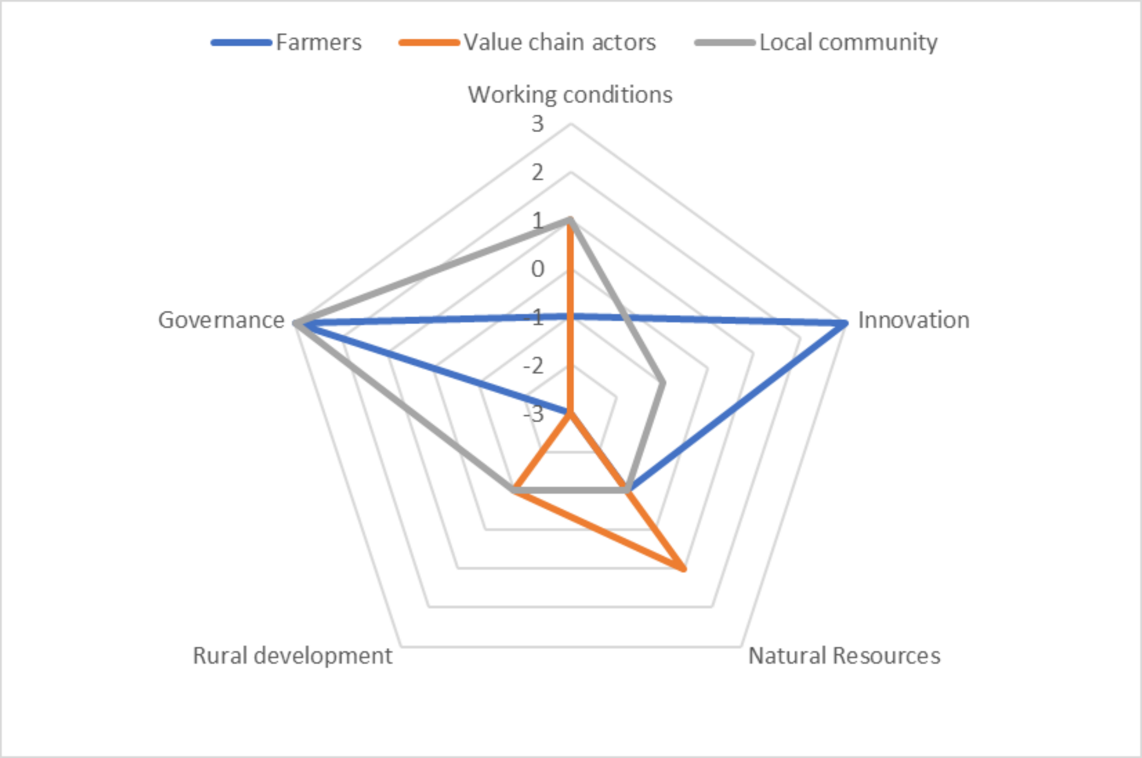

Figure 20 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.6 VC 6: Methyl decenoate from camelina (via metathesis)

This value chain describes the conversion of a high-oleic ("improved") camelina variety (Camelina sativa (L.) CRANTZ) to methyl decenoate via metathesis. This life cycle is compared to conventional ways of providing the same products or services (Figure 21).

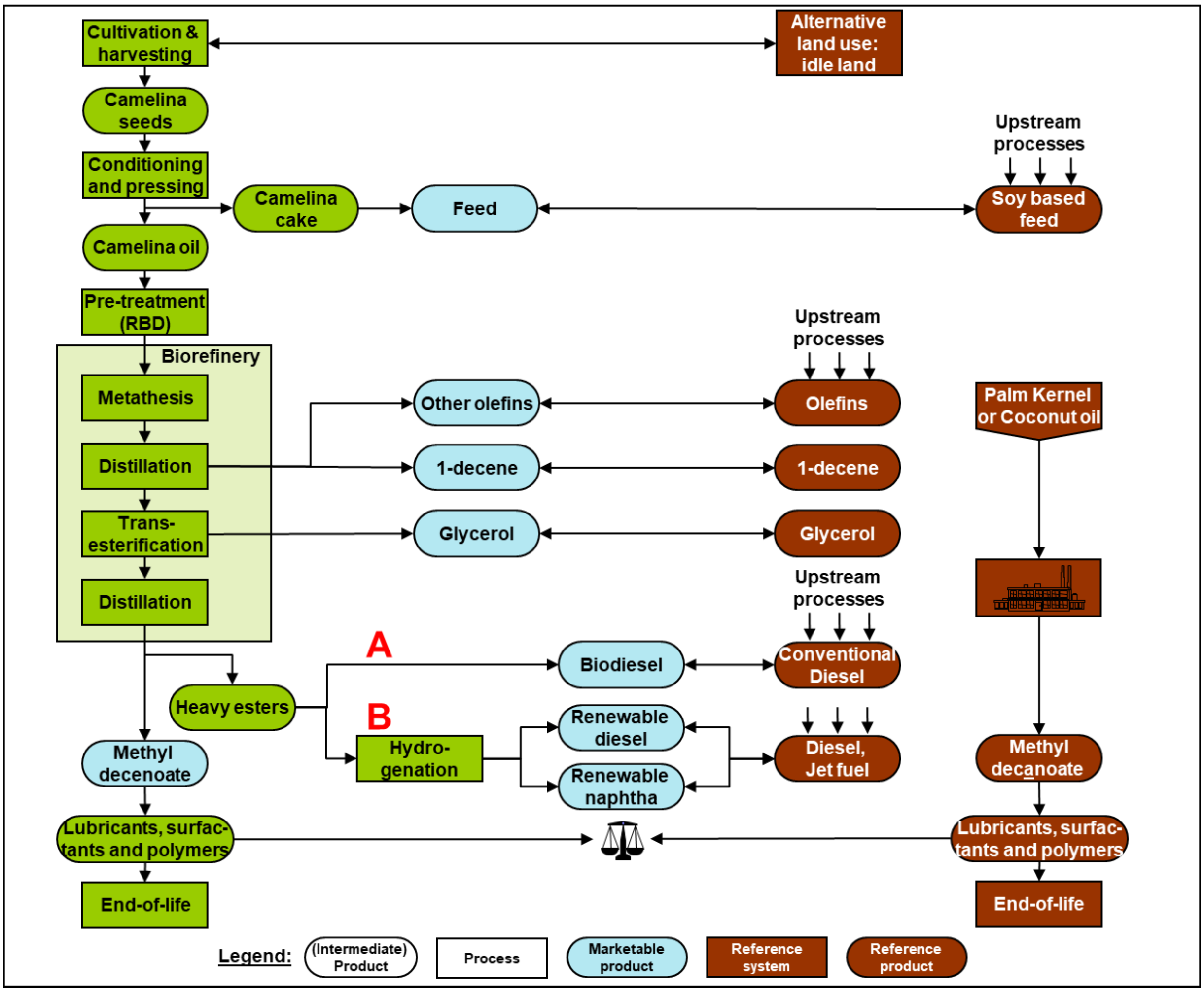

Figure 21 Simplified life cycle comparison for VC 6: methyl decenoate from camelina via metathesis versus methyl decanoate from biogenic resources

Working conditions (Income diversification/ social benefits)

Camelina is an annual C3 crop native to Eurasia. It can be grown both as winter and spring crop. Seeds contain up to 42% of oil and up to 30% of protein. Camelina oil is very rich in polyunsaturated fatty acids, with a composition similar to flax. Camelina has high oil content of 35-38% or higher, desirable lipid composition, novel traits from genetic engineering, and ability to grow in low-input farming systems. It can be used for high-value compounds (e.g. omega-3- fatty acids) or as a part of sustainable crop production systems, as winter cover crop or even as biofuels. The various cropping practices options make camelina a promising crop for crop and income diversification in European regions.

Innovation (Technology development, System versatility, Market prospects)

Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Camelina has wide adaptability to different soil and climate, is tolerant to pest and disease, resistant to drought and can prevent soil erosion. It is a low input crop and can tolerate low water and fertilizer inputs. It is a fast-growing crop and can support biodiversity as a forage resource (nectar and pollen).

Rural development (Local employment, Contribution to rural economy)

Camelina is a short-season crop and it can be grown successfully with rotation with legumes and/or cereals. Currently, camelina is being tested in different cropping systems in Europe in the view of research projects (rotations, double cropping, intercropping). It can also be planted as a winter cover crop. This offers significant opportunities to farmers for income diversification as they can have two crops within a year with different markets. This will result to respective opportunities for rural development in European regions.

Governance (Public commitment to sustainability)

Cultivation of camelina using low quality, marginal land and using it for organic acids fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Climate action: Making the EU climate neutral by 2050

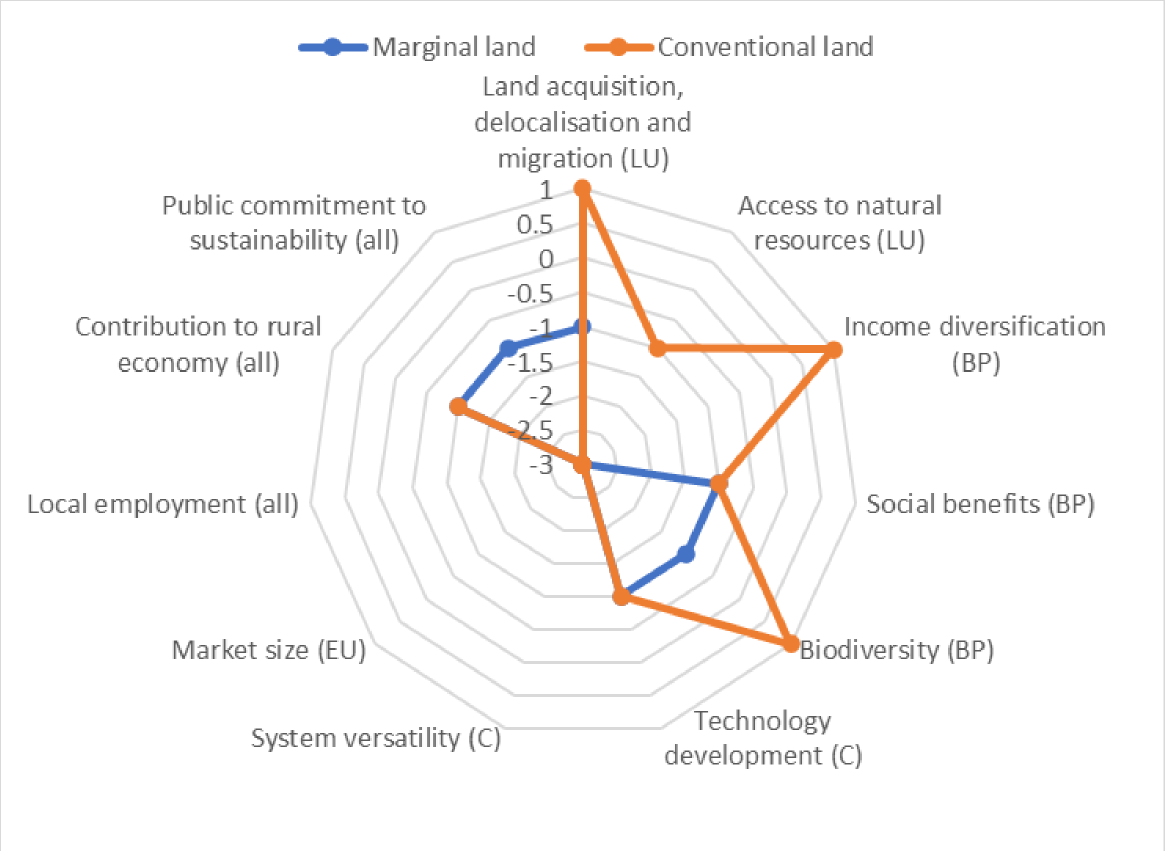

Figure 22 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 22 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Camelina can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems or as cover crop.

Add more benefits from each- rotation and cover crop

tbc

Figure 23 illustrates risk scoring for the impact categories from the three stakeholder groups

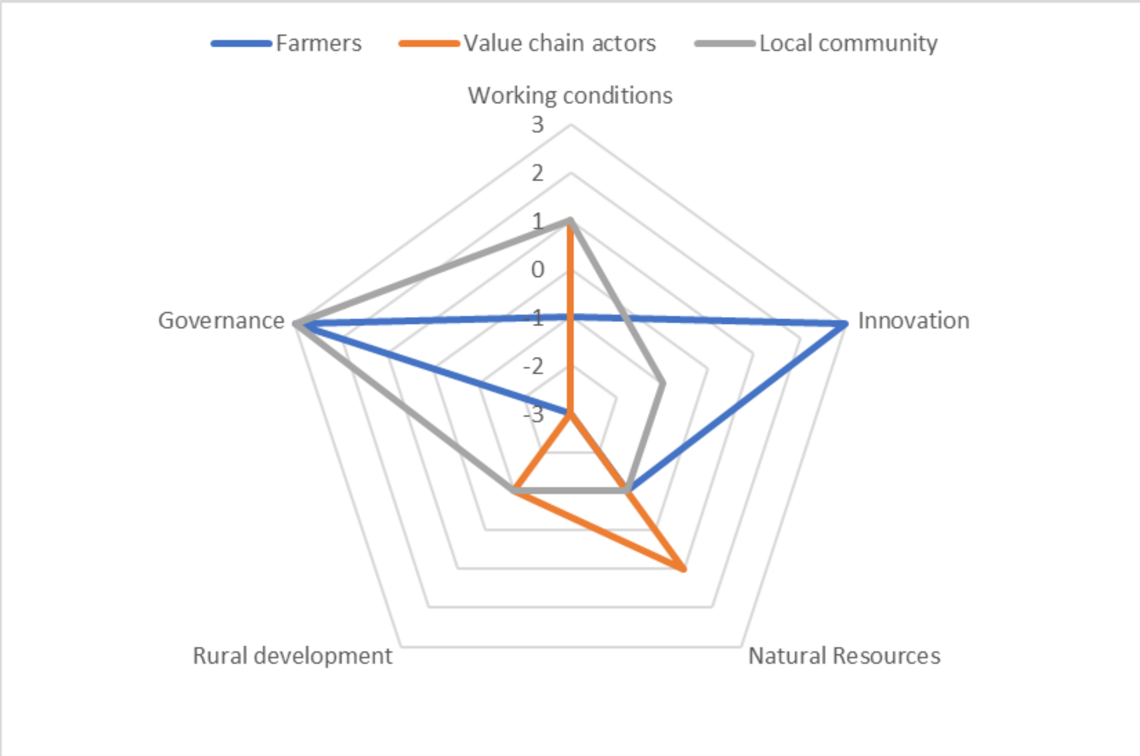

Figure 23 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.7 VC 7: Sebacic acid from castor oil (via alkaline cleavage)

This value chain describes the conversion of castor (Ricinus communis L.) to decanedioic acid (sebacic acid) via several oleochemical processes (among others alkaline cleavage). This life cycle is compared to an alternative way of providing the same products or services through fermentation of petroleum-derived paraffins (Figure 24).

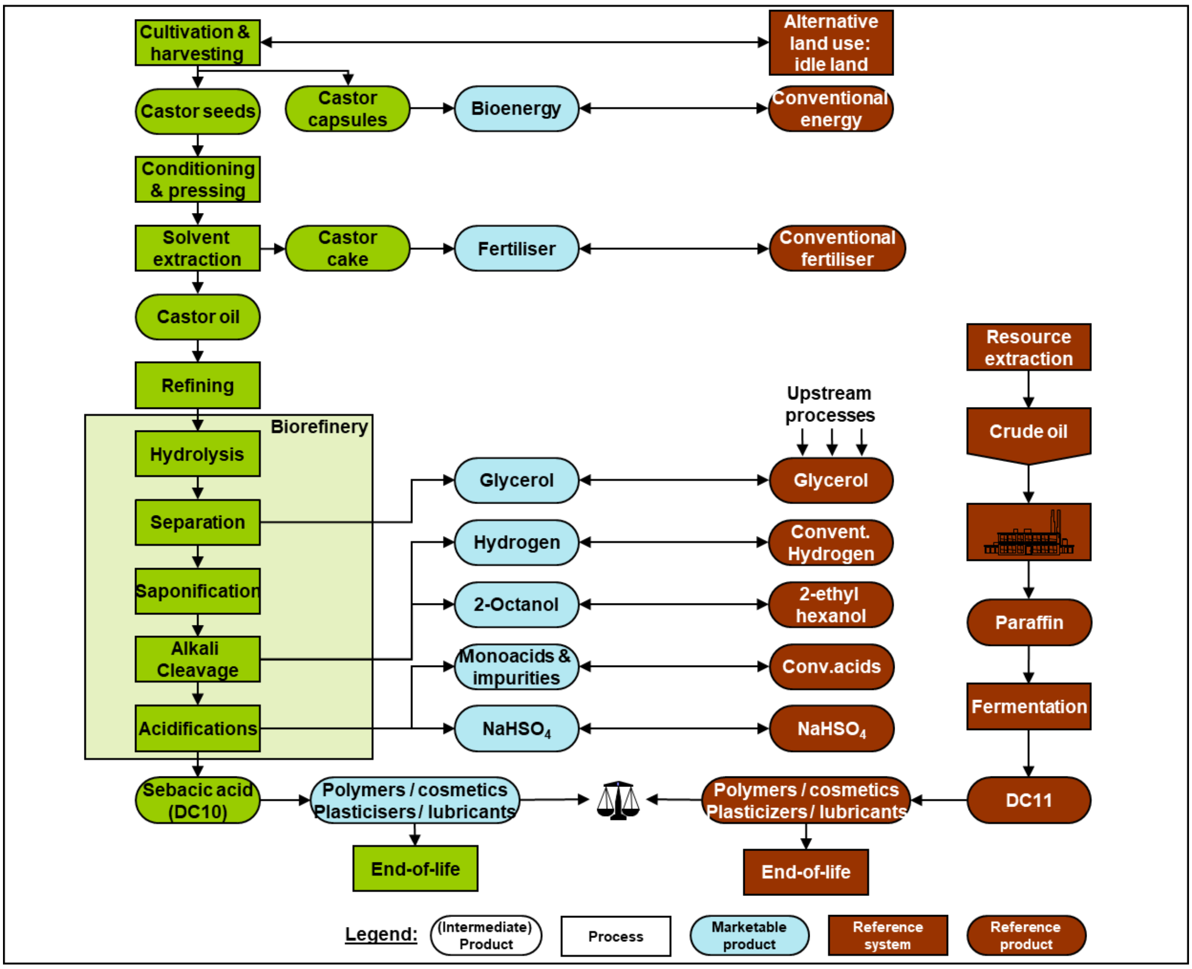

Figure 24 Simplified life cycle comparison for VC 7: products derived from sebacic acid from castor oil versus the same products from paraffins derived through fermentation of petroleum.

Working conditions (Income diversification, social benefits, health and safety)

Castor grows naturally in the whole Mediterranean region. It is a spring crop, able to grow under low water availability. Castor seeds contain up to 50% oil, which is mostly (about 90%) constituted by ricinoleic acid, which is a hydroxy fatty acid with outstanding applications in the bio-based industry.

Innovation (Technology development, System versatility, Market prospects)

Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Castor is adaptable to a wide range of soils and climatic conditions. Optimal growing conditions are well drained, moderately fertile and sandy loams but the crop is tolerant to drought, heat and saline soil conditions. It is not resistant to frost and requires weed, pest and disease control. It can contribute to carbon sequestration and phytoremediation.

Rural development (Local employment, Contribution to rural economy)

Castor is an annual crop that can be cultivated with low tillage practices and can be integrated in rotation systems. This offers significant opportunities to farmers for income diversification as they can have two crops within a year with different markets. This will result to respective opportunities for rural development in European regions.

Governance (Public commitment to sustainability)

Cultivation of castor using low quality, marginal land and using it for organic acids fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Climate action: Making the EU climate neutral by 2050

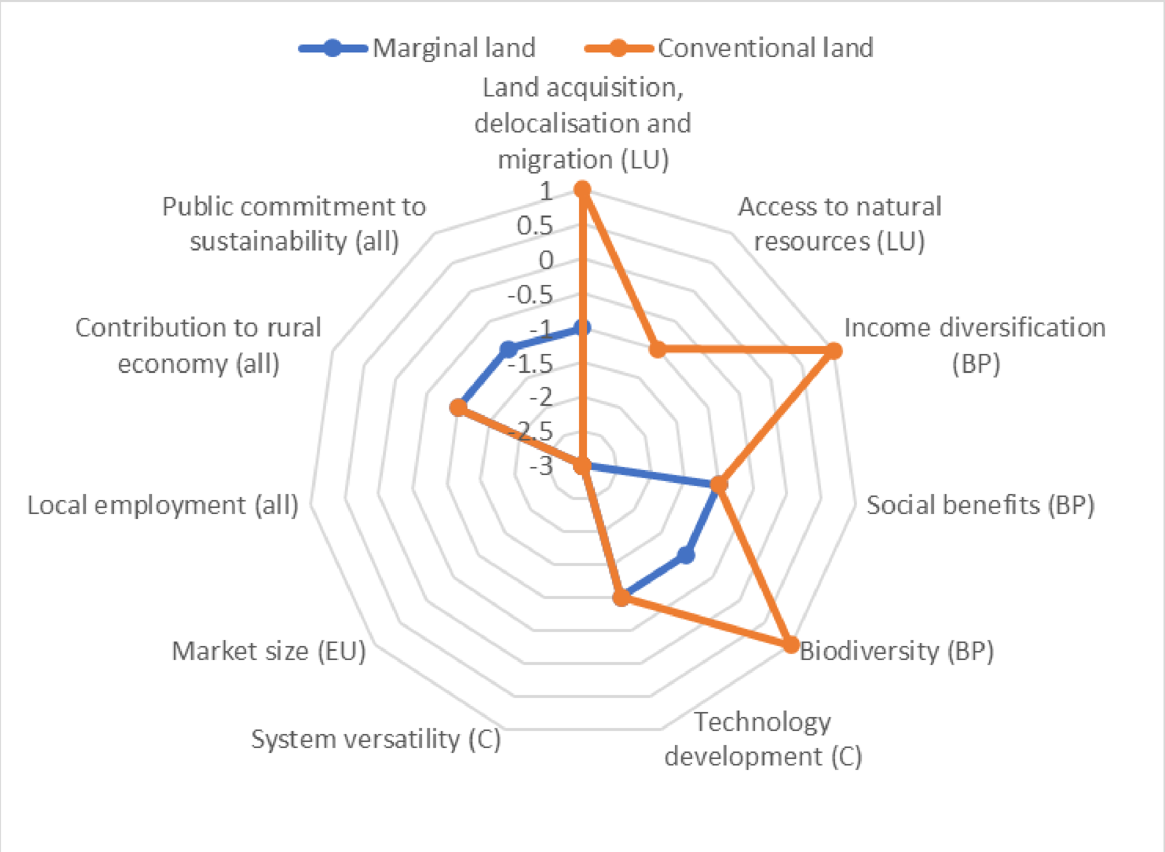

Figure 25 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 25 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Castor can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems or as low tillage crop.

Add more benefits from each- rotation and low tillage

tbc

Figure 26 illustrates risk scoring for the impact categories from the three stakeholder groups

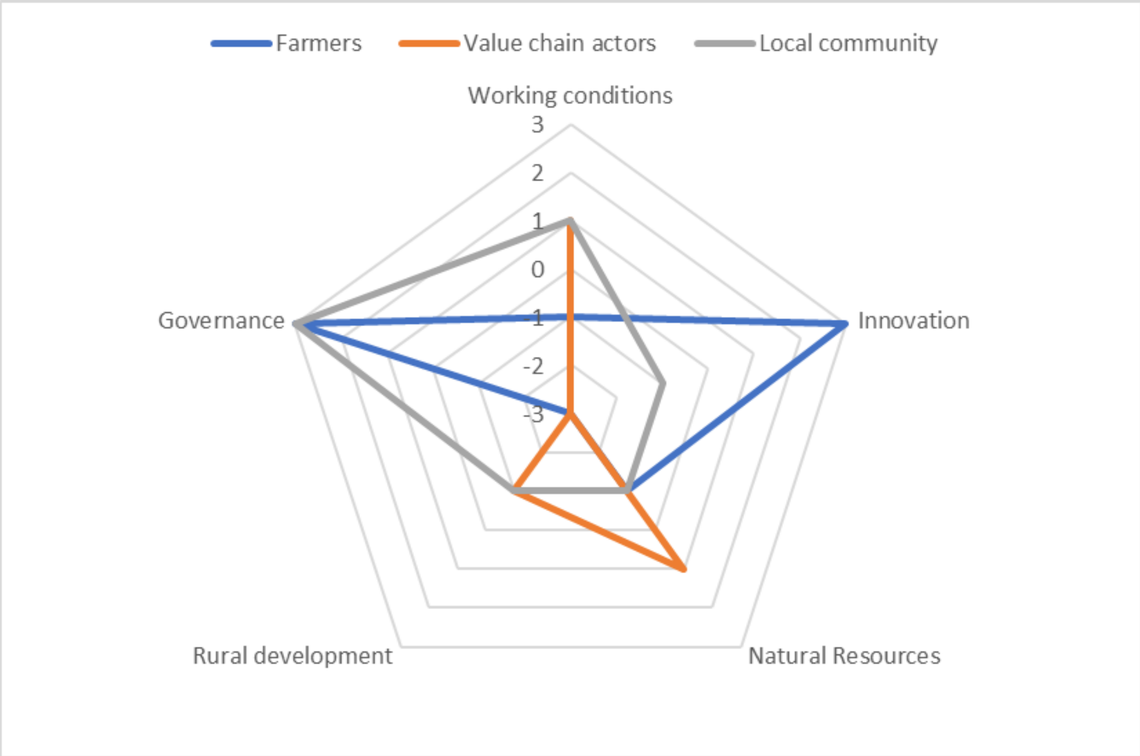

Figure 26 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.8 VC 8: Insulation material from hemp

This value chain describes the production of an insulation material from industrial hemp (Cannabis sativa L.). This life cycle is compared to conventional ways of providing the same products or services (Figure 27).

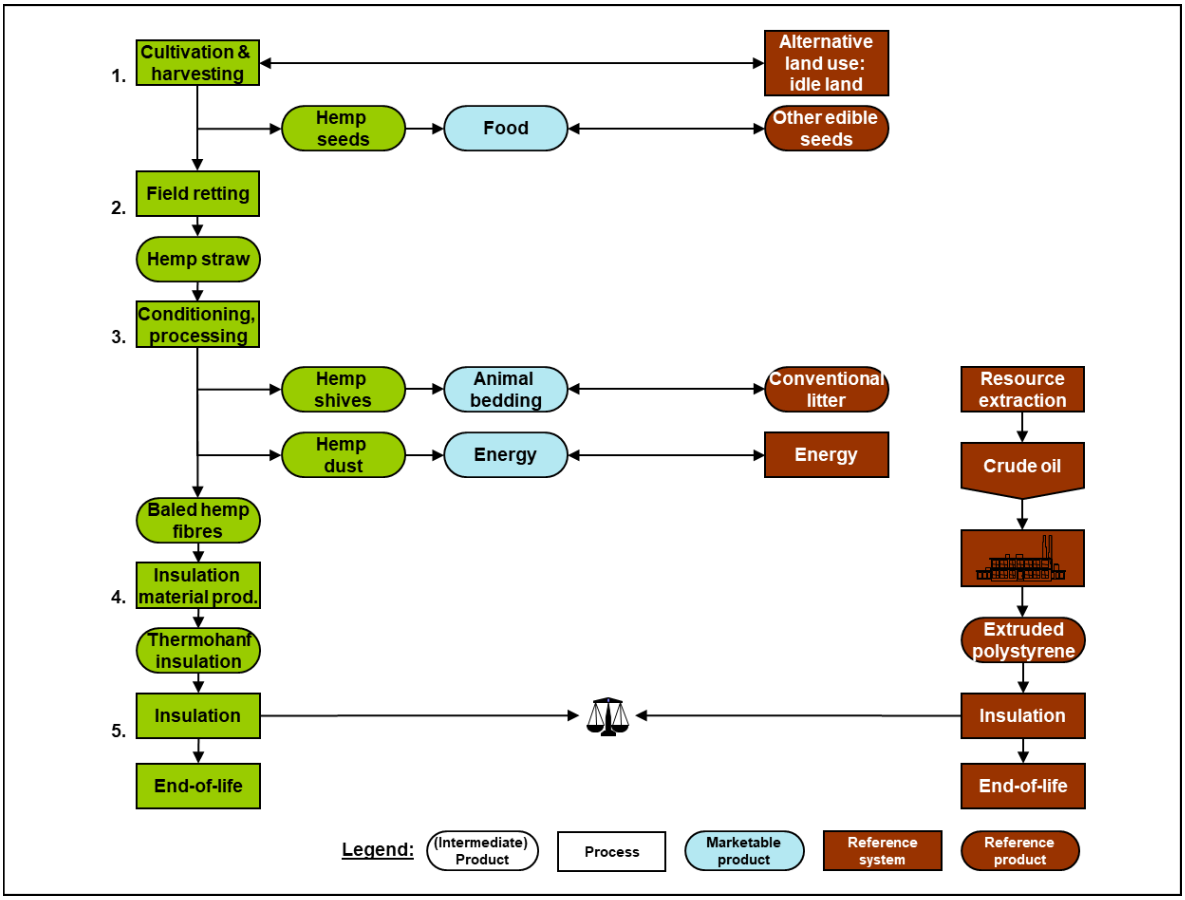

Figure 27 Life cycle comparison for VC 8: insulation material from industrial hemp versus insulation material from fossil resources (e.g. extruded polystyrene)

Working conditions (Income diversification, social benefits, health and safety)

Hemp is an annual spring crop that is traditionally cultivated for its fiber stems. It is a rapid growing crop that can reach a height of 4 m in 100 days. This makes it a good candidate for crop rotation, with similar rotation cycles as corn and sunflower. Although industrial hemp is considered as fiber crop, high-value bio-products can be produced from all plant parts (stems, leaves, seeds and flowers). The fibres of its stem are being used for paper and pulp, insulation mats, bio-composites and textiles. The shivs (the woody part of its stem) can be used as construction material, for animal bedding, garden mulch, etc. The seeds can be consumed as food and/or feed, the seeds oil can be used either for food and feed consumption and/or for cosmetics and heath care products. The flowers have numerous pharmaceutical uses from THC (tetrahydrocannabinol), CBD (cannabidiol) and other cannabinoids. The multitude of products and end uses makes hemp a very good option for income diversification in European rural areas.

Innovation (Technology development, System versatility, Market prospects)

Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Hemp can be adapted to all European agroecological regions as a high yield, spring, fibre crop. It is tolerant to water stress, pests and diseases and can be grown on marginal land and/or land with heavy metals. It has no special needs for pesticides / herbicides. But requires irrigation in south Europe. It can contribute to carbon sequestration and phytoremediation.

Rural development (Local employment, Contribution to rural economy)

Hemp is an annual crop that can be cultivated with low tillage practices and can be integrated in rotation systems. This offers significant opportunities to farmers for income diversification as they can have two crops within a year with different markets. This will result to respective opportunities for rural development in European regions.

Governance (Public commitment to sustainability)

Cultivation of hemp using low quality, marginal land and using it for insulation materials fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Climate action: Making the EU climate neutral by 2050

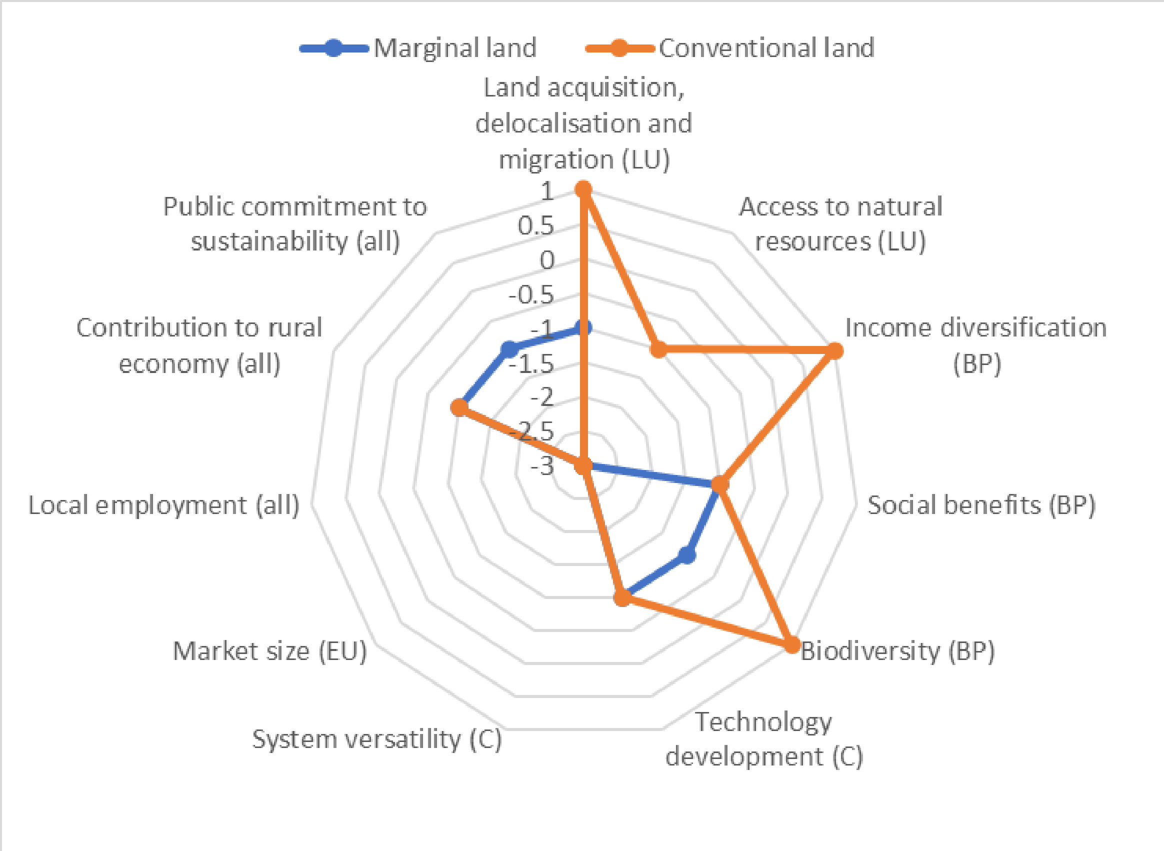

Figure 28 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 28 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Castor can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems or as low tillage crop.

Add more benefits from each- rotation and low tillage

tbc

Figure 29 illustrates risk scoring for the impact categories from the three stakeholder groups

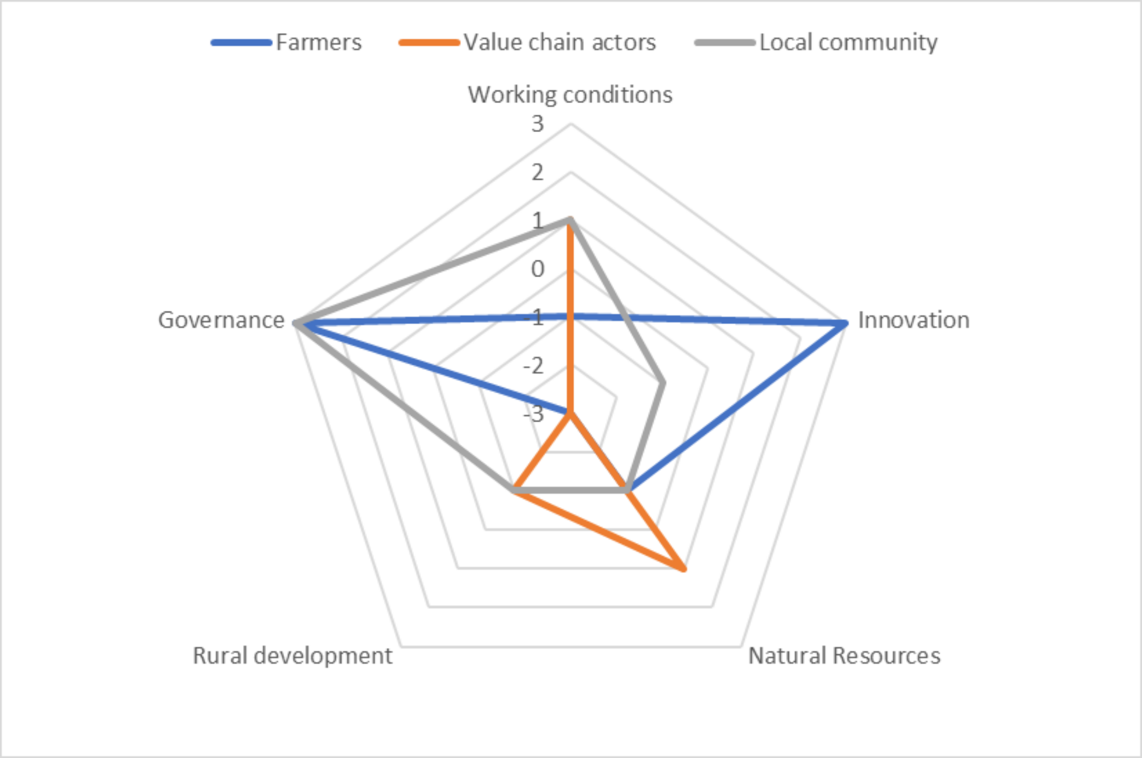

Figure 29 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.9 VC 9: Biogas/biomethane from sorghum

This value chain describes the production of biogas from sorghum (Sorghum bicolor (L.) MOENCH) as a substrate. This life cycle is compared to conventional ways of providing the same products or services (Figure 30).

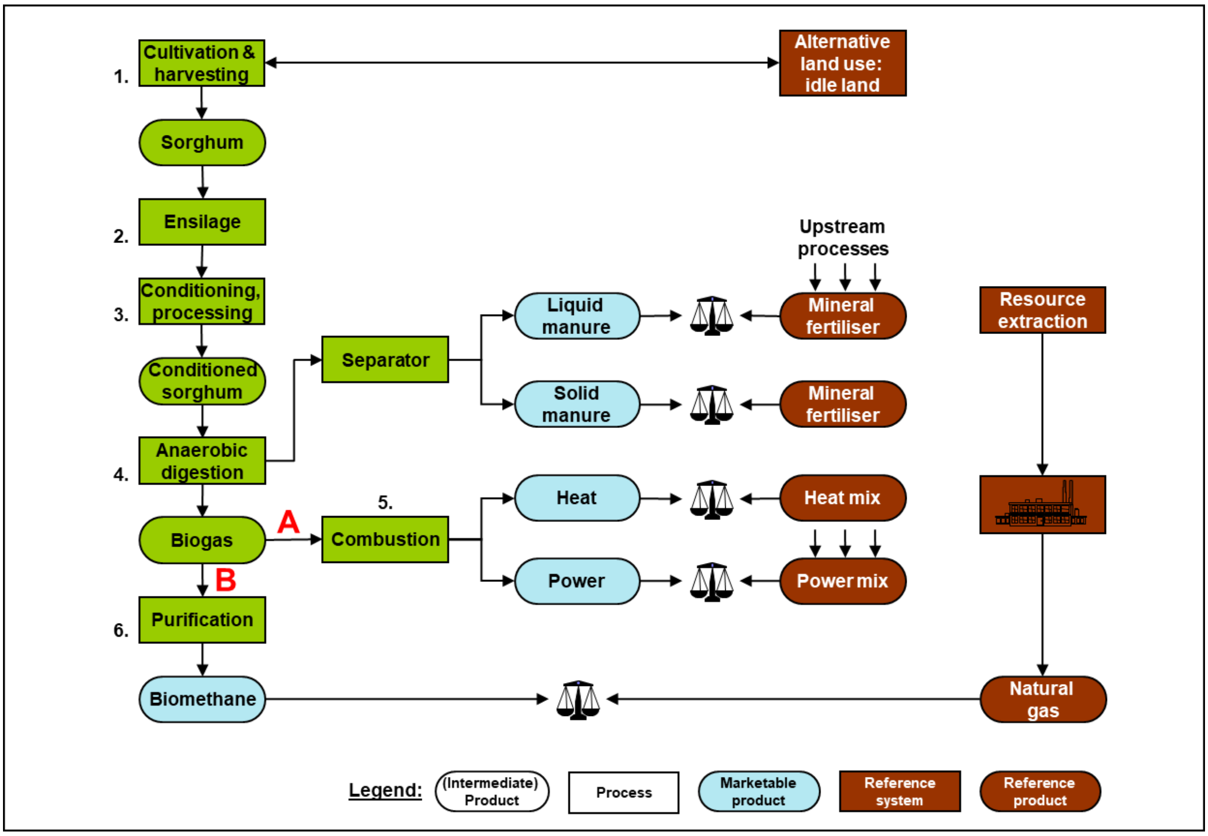

Figure 30 Life cycle comparison for VC 9: biogas/biomethane from sorghum versus natural gas.

Working conditions (Income diversification, social benefits, health and safety)

Sorghum is an annual herbaceous spring C4 crop with erect stems that can reach 5 m height. Sweet sorghum is a multipurpose plant. Its seeds can be used as animal feeds and the stalks as building materials. The whole crop, its juice, seeds and bagasse can be used for biogas and biofuels.

Innovation (Technology development, System versatility, Market prospects)

Biogas from sorghum presents very good opportunities for the heat and electricity markets especially for Combined Heat and Power (CHP) with full year industrial heat demand. The digestate can be used as fertiliser. tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

The crop is tolerant to drought, toxic soil conditions, water logging, salinity, alkalinity and high temperatures. It exhibits high water use and nutrient use efficiency. Pests and diseases can be controlled by crop rotation with non-grass crops such as soybean, etc.

Rural development (Local employment, Contribution to rural economy)

Sorghum is an annual crop that can be cultivated with low tillage practices, as cover crop and can be integrated in rotation systems. This offers significant opportunities to farmers for income diversification as they can have two crops within a year with different markets. This will result to respective opportunities for rural development in European regions.

Governance (Public commitment to sustainability)

Cultivation of sorghum using low quality, marginal land and using it for biogas fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Clean energy: Clean energy
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Climate action: Making the EU climate neutral by 2050

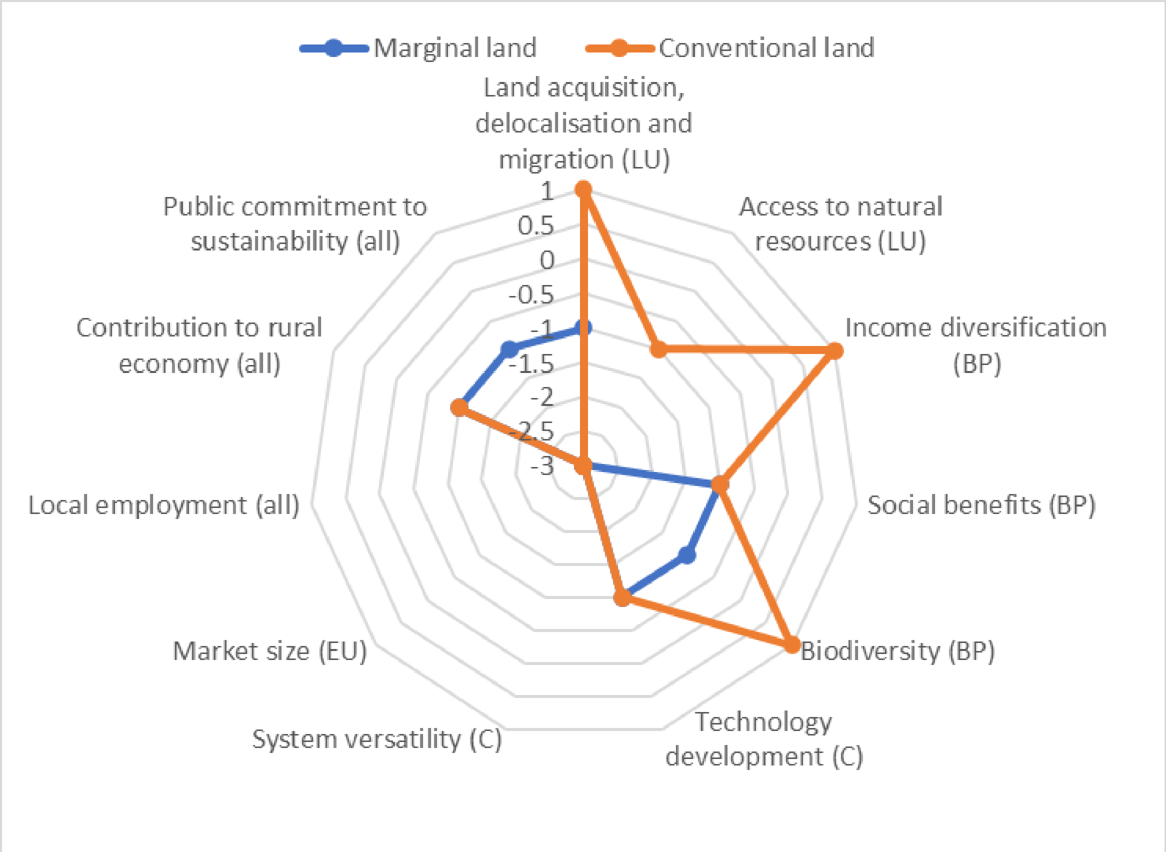

Figure 31 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 31 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Sorghum can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems, as cover crop or as low tillage crop.

Add more benefits from each- rotation, low tillage and cover crop

Tbc

Figure 32 illustrates risk scoring for the impact categories from the three stakeholder groups

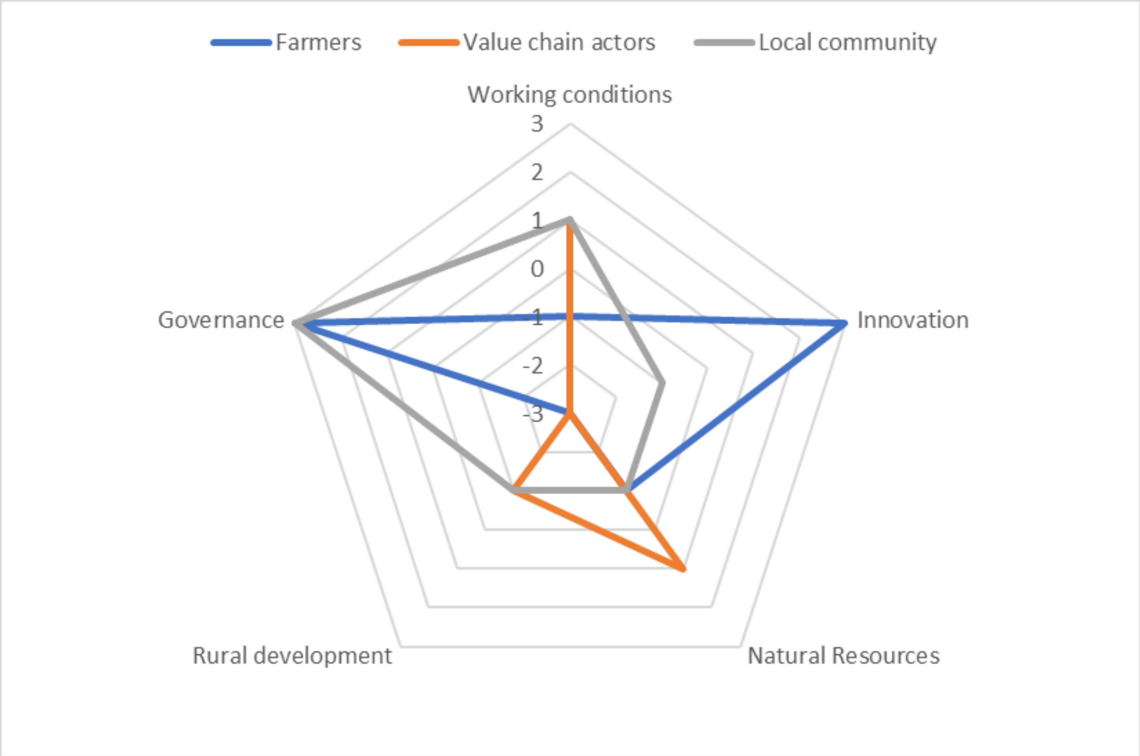

Figure 32 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.3.3.10 VC 10: Adhesives from lupin

This value chain describes the conversion of Andean lupin (Lupinus mutabilis SWEET) to micellar lupin protein (MLP), which can be used as a food packaging adhesive. This life cycle is compared to conventional ways of providing the same products or services (Figure 33).

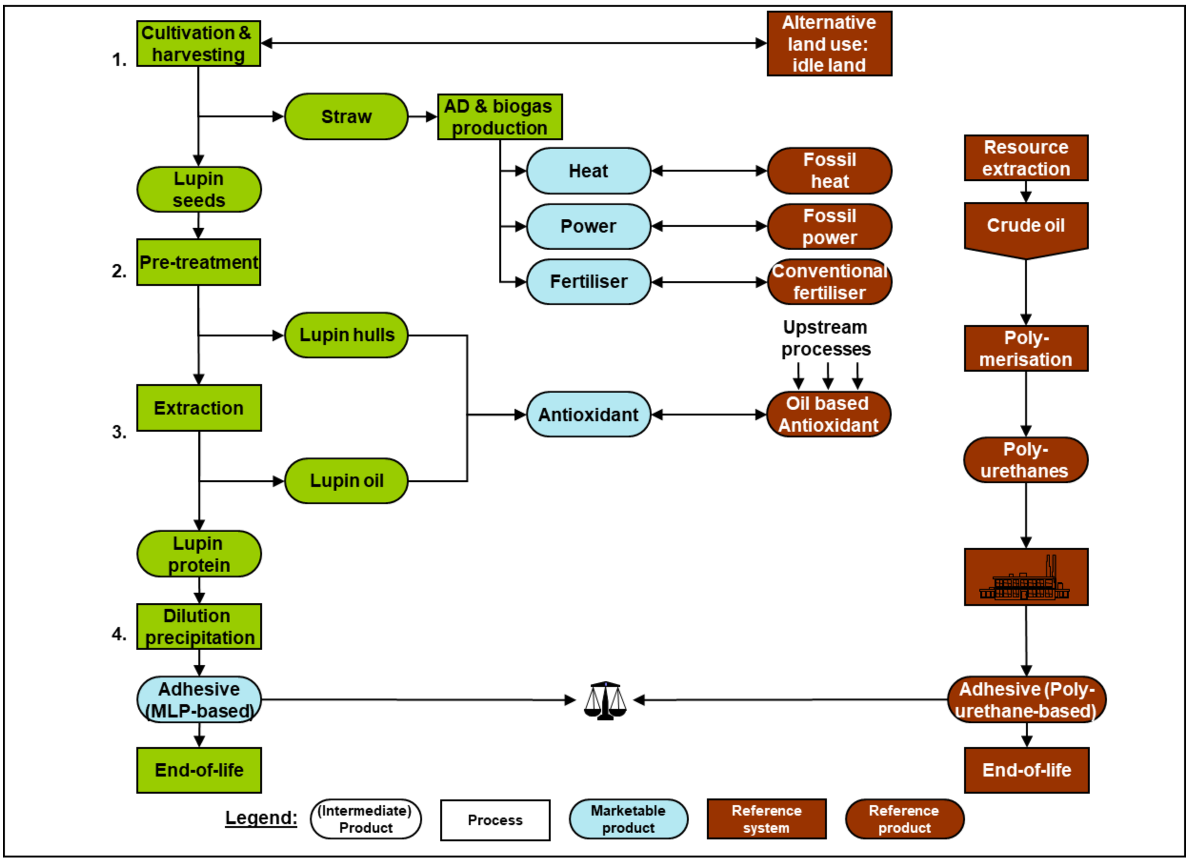

Figure 33 Life cycle comparison for VC 10: adhesives from lupin versus adhesives from fossil resources.

Working conditions (Income diversification, social benefits, health and safety)

Lupin is native to South America but now it can be grown in Europe in moderately cool areas. Andes Lupin can be grown in north-central Europe in summer and in Mediterranean Europe in winter. Lupin mutabilis is known to grow well in marginal lands due to their ability to fix nitrogen, mobilise soil phosphate and they require minimum inputs. Some varieties of Lupin seeds has high (20%) oil content, protein (40%) and carbohydrates (oligosaccharides) therefore based on pre-industrial processing available lupin properties can be optimized to produce different high added value products for consumers e.g. high nutrient content foods, anti-aging cosmetics, new biomaterials.

Innovation (Technology development, System versatility, Market prospects)

Tba

Natural resources (Biodiversity, Land use and development, Access to natural resources)

Lupin can be grown in marginal soil conditions and is a good option for rotational and cover cropping. It is tolerant to pests and diseases. It can be used for land reclamation in volcanic soil as it can regenerate soils. The crop has also ecological benefits through prevention of soil-erosion, increase soil carbon sequestration and nitrogen fixing properties.

Rural development (Local employment, Contribution to rural economy)

Sorghum is an annual crop that can be cultivated with low tillage practices, as cover crop and can be integrated in rotation systems. This offers significant opportunities to farmers for income diversification as they can have two crops within a year with different markets. This will result to respective opportunities for rural development in European regions.

Governance (Public commitment to sustainability)

Cultivation of sorghum using low quality, marginal land and using it for biogas fits well to certain policy areas and instruments in the European Green Deal. These include:

- Biodiversity: Measures to protect our fragile ecosystem
- Sustainable agriculture: Sustainability in EU agriculture and rural areas thanks to the common agricultural policy (CAP)
- Clean energy: Clean energy
- Eliminating pollution: Measures to cut pollution rapidly and efficiently
- Sustainable industry: Ways to ensure more sustainable, more environmentally respectful production cycles
- Climate action: Making the EU climate neutral by 2050

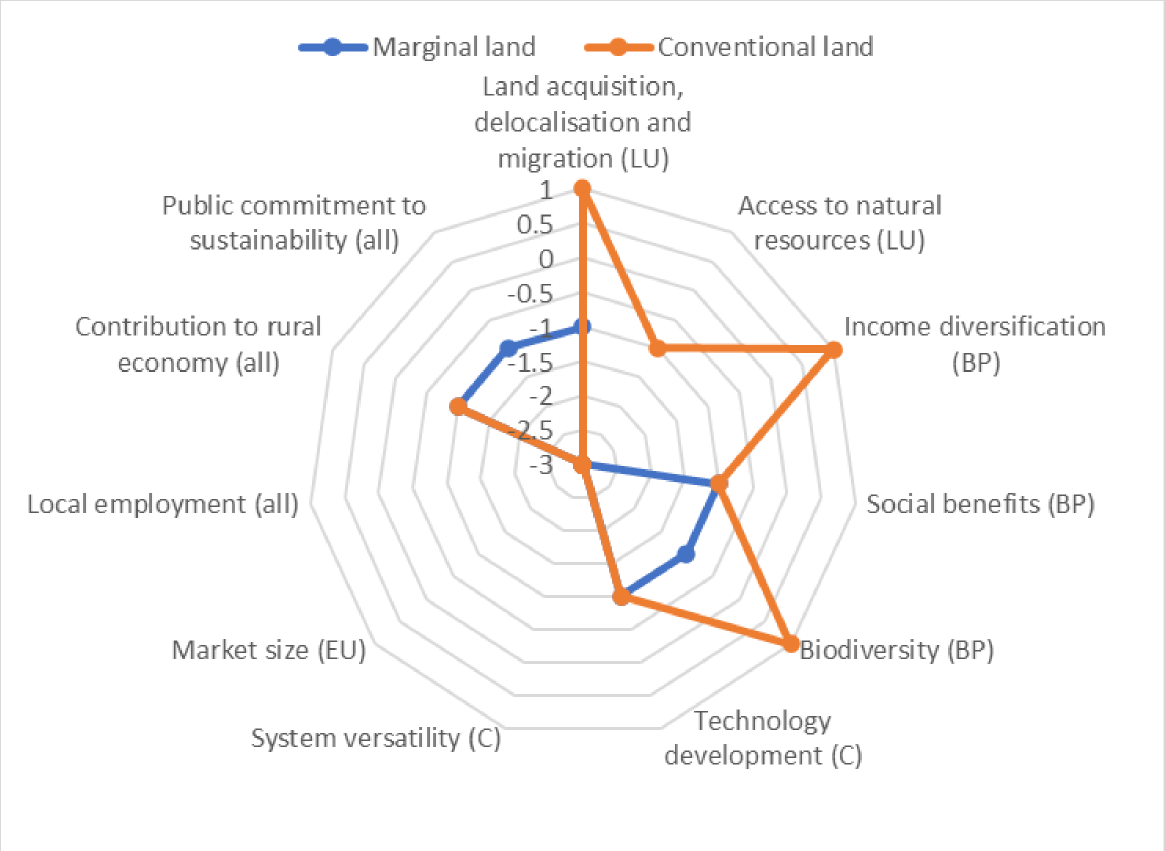

Figure 34 Comparison of social risks for category indicators and value chain stages in marginal and conventional land

Figure 34 illustrates a comparison of the value chain for marginal and conventional land. Social risks for the access to natural resources, income diversification and biodiversity are higher in conventional arable land than in marginal. Sorghum can be a good option for marginal land, but it is considered of high social risk for conventional arable land in terms of land acquisition, biodiversity and income diversification primarily due to competition with other food and feed crops. The latter can be compensated if the crop is cultivated as part of rotation systems, as cover crop or as low tillage crop.

Add more benefits from each- rotation, low tillage and cover crop

tbc

Figure 35 illustrates risk scoring for the impact categories from the three stakeholder groups

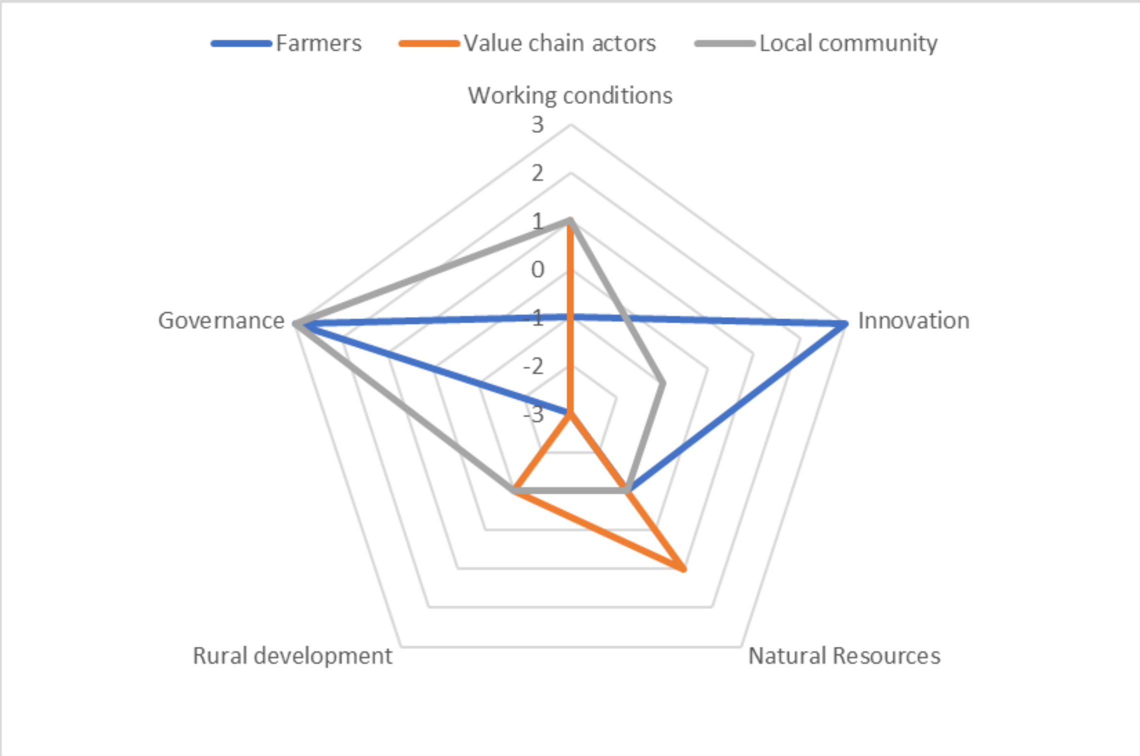

Figure 35 Risk scoring for the impact categories from the three stakeholder groups

tbc

5.4 Interpretation

This section presents an identification of the significant issues of the analysed life cycles, followed by an evaluation of the study and the conclusions that can be drawn from the assessment.

5.4.1 Value chains

Tbc after interviews from this summer are processed

Analysis will be presented per scale of application (small biogas digestors, small scale heat) and per market (readiness- e.g bioenergy biofuels and emerging biobased chemicals/ products)

5.4.2 Agro-ecological zones

It is the aim of the MAGIC project to establish a basis for cultivation of marginal lands in Europe. For this reason, geographical coverage for the sustainability assessment is focused on European countries and the differing growing conditions and cultivation practises in Europe are considered. This is achieved by categorising the various conditions and yield potentials that can be found in Europe based on the climatic zones identified by [Metzger et al. 2005]. For the MAGIC project, these climatic zones are aggregated into three large agroecological zones (AEZ) as specified in Figure 26. On the one hand more distinctions would exceed the scope of the analysis and on the other hand conditions vary strongly across Europe (Ref D6.4).

Figure 36 Major geographical/climatic zones in Europe; yellow spots indicate new and established field trials.

The following three aggregated agro-ecological zones are defined for the MAGIC project:

- AEZ 1 – Mediterranean (MED),
- AEZ 2 – Atlantic (ATL), and
- AEZ 3 – Continental & Boreal (CON).

Within these zones, different biophysical constraints are prevailing which hamper the growth of industrial crops. The two most important constraints in each zone have been identified by [von Cossel et al. 2018[25]] and corresponding yields were set by the partners.

5.4.2.1 Crop performance in agro-ecological zones

The information in the sub section for agro-ecological zones focuses on the crop specific performance and any risks that have been considered of social relevance by the various stakeholders that participated in the analysis.

tbc

AEZ 1 – Mediterranean (MED)

Miscanthus: Miscanthus is suitable for Mediterranean agroclimatic zone, exhibits high yields and resists water stress by decreasing photorespiration i.e. by losing leaf area and increasing root growth[26].

Poplar: Poplar has shown positive energy balance and high energy efficiency [27] when grown in Mediterranean agroclimatic zone.

Switchgrass: Switchgrass is considered a suitable crop for less fertile, erosive lands and requires low inputs (fertilisation and water). Due to deep rooting system, they survive in Mediterranean conditions and has high water use efficiency compared to carbohydrate crops like maize[28].

Willow: Willow is a suitable short rotation woody crops which are considered ideal energy crops because their yield in high in marginal soil and climatic condition, thus making them suitable for Mediterranean zone[29].

Safflower: Safflower grows well in Mediterranean conditions as they are best suited to hot dry climates. This is because of their deep root system which can uptake moisture and nutrients

[25] von Cossel, M., Iqbal, Y., Scordia, D., Cosentino, S. L., Elbersen, B., Staritsky, I., van Eupen, M., Mantel, S., Prysiazhniuk, O., Maliarenko, O., Lewandowski, I. (2018): Low-input agricultural practices for industrial crops on marginal land (Deliverable D4.1). In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, University of Hohenheim, Stuttgart (Hohenheim), Germany. http://magich2020.eu/documents-reports/

[26] Triana F, Nassi o Di Nasso N, Ragaglini G, Roncucci N, Bonari EJGB. Evapotranspiration, crop coefficient and water use efficiency of giant reed (Arundo donax L.) and miscanthus (Miscanthus× giganteus Greef et Deu.) in a Mediterranean environment. 2015;7(4):811-9.

[27] Nassi o Di Nasso N, Guidi W, Ragaglini G, Tozzini C, Bonari EJGB. Biomass production and energy balance of a 12-year-old short-rotation coppice poplar stand under different cutting cycles. 2010;2(2):89-97.

[28] Giannoulis K, Danalatos NJB, Bioenergy. Switchgrass (Panicum virgatum L.) nutrients use efficiency and uptake characteristics, and biomass yield for solid biofuel production under Mediterranean conditions. 2014;68:24-31.

[29] Mauromicale G, Sortino O, Pesce GR, Agnello M, Mauro RPJIC, Products. Suitability of cultivated and wild cardoon as a sustainable bioenergy crop for low input cultivation in low quality Mediterranean soils. 2014;57:82-9.

(like N) from deep layer of soil. This makes them suitable crop for rotational cropping and reduction of N leaching into the ground water[30]. Safflower is used for oil and its meal which is high in protein and fiber.

Camelina: Camelina has highest seed yields in Mediterranean climates (Berti et al., 2011, Masella et al., 2014)[31].

Castor: Castor is well suited for Mediterranean zone and in slightly favourable temperature with regular irrigation is found to significantly increase their productivity[32].

Industrial hemp: Hemp has shown good productivity in semi-arid Mediterranean, but their productivity is affected by water shortage and high air temperature. Therefore, manipulation of sowing date is recommended to avoid these unfavorable climatic conditions[33].

Sorghum: Sorghum is drought tolerant crop which has ability to extract water from deep-soil and ability to give high yield in rain-fed, water scare Mediterranean conditions[34].

Lupin: Lupin is well adapted to Mediterranean conditions and considered profitable crops (Siddique et al., 1993)[35].

The main risks with social relevance in the Mediterranean agro-climatic region concern the crops' adaptability to long dry periods and years with limited rainfall as well as deterioration of soil quality due to desertification. These lead to gradual land abandonment due to low yield and limited profitable crop opportunities for farmers.

AEZ 2 – Atlantic (ATL)

Miscanthus: Miscanthus are C4 crops with higher radiation, water and nitrogen use efficiency are prefers warm temperate climatic conditions to initiate the growth. They grow from dormant winter rhizome when soil temperature reach 10-12 °C[36].

[30] Yau S-K, Ryan JJIc, products. Response of rainfed safflower to nitrogen fertilization under Mediterranean conditions. 2010;32(3):318-23.
[31] Berti M, Gesch R, Eynck C, Anderson J, Cermak SJIc, products. Camelina uses, genetics, genomics, production, and management. 2016;94:690-710.
[32] Zanetti F, Chieco C, Alexopoulou E, Vecchi A, Bertazza G, Monti AJIC, et al. Comparison of new castor (Ricinus communis L.) genotypes in the mediterranean area and possible valorization of residual biomass for insect rearing. 2017;107:581-7.
[33] Cosentino SL, Riggi E, Testa G, Scordia D, Copani VJIc, products. Evaluation of European developed fibre hemp genotypes (Cannabis sativa L.) in semi-arid Mediterranean environment. 2013;50:312-24
[34] Farré I, Faci JMJAwm. Comparative response of maize (Zea mays L.) and sorghum (Sorghum bicolor L. Moench) to deficit irrigation in a Mediterranean environment. 2006;83(1-2):135-43.
[35] Leport L, Turner N, French R, Tennant D, Thomson B, Siddique KJEJoA. Water relations, gas exchange and growth of cool-season grain legumes in a Mediterranean-type environment. 1998;9(4):295-303.
[36] Lewandowski I, Clifton-Brown J, Scurlock J, Huisman WJB, Bioenergy. Miscanthus: European experience with a novel energy crop. 2000;19(4):209-27.

Poplar: Poplar are low input crops which can be grown on marginal lands of warm-temperate climatic zones because warm temperature supports the rapid growth of plant, and they have high photosynthetic capacity aided by their large leaf area. All this makes them suitable for Atlantic North and South[37].

Switchgrass

Willow: Willow is considered suitable crop in the Atlantic region.

Safflower: Safflower crops has both winter and spring varieties and they can grow in marginal soil and very low rainfall conditions and suitable in Atlantic agroclimatic conditions.

Camelina

Castor

Industrial hemp: Hemp is suitable in wide range of climatic conditions and a study shows that Hemp yield was found to be slightly lower for the countries in Atlantic zone (Netherlands and United Kingdom) compared to Italy[38].

Sorghum

Lupin: Lupin is found to be suitable crop for this zone and has potential to replace food oil crop soybean.

The main risks with social relevance in the Atlantic agro-climatic region concern

AEZ 3 – Continental & Boreal (CON)

Miscanthus: Miscanthus grows well in Continental and Boreal region of Europe and production level is good even in lower quality soil with little fertilization and protection from pests and diseases. Cultivation and harvesting of miscanthus can be adopted using the cereal production systems.

Poplar: Poplar is considered a good short rotation crops for boreal climatic zones because of their fast growth rate in summer air temperature of above 20°C

[37] Djomo SN, El Kasmioui O, De Groote T, Broeckx L, Verlinden M, Berhongaray G, et al. Energy and climate benefits of bioelectricity from low-input short rotation woody crops on agricultural land over a two-year rotation. 2013;111:862-70.
[38] Struik P, Amaducci S, Bullard M, Stutterheim N, Venturi G, Cromack HJIc, et al. Agronomy of fibre hemp (Cannabis sativa L.) in Europe. 2000;11(2-3):107-18.

which his. The biomass yield from boreal climatic system is not very different from the warm-temperate regions, if the appropriate crop management practices are applied[39].

Switchgrass: Switchgrass is suitable crop with good production level for the continental agroclimatic region of Europe.

Willow: Willow is considered a good short rotation crop species for boreal climatic zones because of their fast growth rate in summer air temperature of above 20°C
which his. The biomass yield from boreal climatic system is not very different from the warm-temperate regions, if the appropriate crop management practices are applied (38).

Safflower: Safflower can also be grown in continental and boreal climatic regions, but the crop does not mature until late autumn.

Camelina: Camelina is well adapted to continental and boreal conditions because there are both spring and winter biotypes available in the market.

Castor: Castor is a spring crop and is very sensitive to temperature but can grow in low water available conditions. It is a suitable crop in Continental and Boreal conditions.

Industrial hemp: Hemp is adapted to wide variety of environment and is multipurpose crops - fiber and oil.

Sorghum

Lupin: Lupin is a crop suited to most of the continental European countries and are leguminous crops with a capability to fic nitrogen from atmosphere.

The main risks with social relevance in the Continental and Boreal agro-climatic region concern

[39] Weih MJCJoFR. Intensive short rotation forestry in boreal climates: present and future perspectives. 2004;34(7):1369-78.

5.4.3 Stakeholder Groups

Tbc after interviews from this summer are processed

5.4.3.1 Stakeholders’ ranking or risks within the impact categories

Figure 37 Overall risk scoring of the impact categories by the three stakeholder groups for the understudy biobased value chains

Farmers consider as higher risks of the understudy value chains the lack of governance and the highly innovative nature.

Value chain actors consider as higher risks of the understudy value chains the access and resource efficient use of natural resources and the working conditions, including health and safety and job skills.

Local community consider as higher risks of the understudy value chains the lack of governance, the highly innovative nature and the working conditions, including income and job creation.

tba

5.4.3.2 Stakeholders ranking of risks within impact categories across value chains

Tbc

6 Conclusion

Tbc after interviews from this summer are processed

Annexes

Life cycle inventory- VC 1: Miscanthus, Pyrolysis, Industrial Heat

Stakeholder category	Category indicator (Value chain stage)	Sub indicator	Result	Score for risks	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?	Miscanthus is a perennial crop and can be cultivated in low quality land, alongside field boundaries, etc. the harvesting window allows its integration with cereal cropping in a region.	-1	Agricultural income statistics, literature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas	0	
Value chain actors	Technology development (C)	TRL	TRL: 6-7	-1	
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels	In principle multiple feedstocks can be used. The oil can be stored and transported over longer distances (in comparison to the untreated feedstock).	-3	
	Market size (EU)	End product market capacity & demand projections	Limited by industrial heat demand, and by the presence of district heating.	-1	
Local community	Biodiversity (BP)	Crop traits and adaptation	Miscanthus is a perennial crop and can add to the landscape diversity	-1	
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy		3	
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass	6.5-8 (CON); 8-11.5 (MED)	-1	
	Local employment (all)	No. of direct Jobs	Jobs – paper	-1	
	Contribution to rural economy (all)			-1	

	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.	0	

Life cycle inventory- VC 2: Synthetic Natural Gas (SNG) from poplar (via gasification)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels	Can serve as baseload / controllable source of green energy	-1	
	Market size (EU)	End product market capacity & demand projections	Electricity markets Limit to dispose residual heat in the neighbourhood	-1	
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life cycle inventory- VC 3: Ethanol from switchgrass (via hydrolysis & fermentation)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels	Storage and transport options. These installations can also produce building blocks for the chemical industry.		
	Market size (EU)	End product market capacity & demand projections	Transport fuels		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life Cycle Inventory - VC 4: Biotumen from willow (via pyrolysis)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, literature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels	The product can be stored and transported over longer distances.		
	Market size (EU)	End product market capacity & demand projections	Roofing material replacing fossil bitumen		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life Cycle inventory- VC 5: Organic acids from safflower (via oxidative cleavage)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels			
	Market size (EU)	End product market capacity & demand projections	Azelaic acid has a potential application as plasticisers and polymers.		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life Cycle inventory - VC 6: Methyl decenoate from camelina (via metathesis)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels			
	Market size (EU)	End product market capacity & demand projections	Wide market applications in agriculture, chemicals, cosmetics, food and fuels		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life cycle inventory- VC 7: Sebacic acid from castor oil (via alkaline cleavage)

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels			
	Market size (EU)	End product market capacity & demand projections	Wide market applications for plasticizers, lubricants, solvents, adhesives, and chemical intermediates		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life Cycle inventory- VC 8: Insulation material from hemp

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels			
	Market size (EU)	End product market capacity & demand projections	Insulation for buildings, car manufacturers, etc.		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life cycle inventory- VC 9: Biogas/biomethane from sorghum

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 8-9		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels	possibilities to further process digestate to bio-fertiliser.		
	Market size (EU)	End product market capacity & demand projections	Market size ranges from small scale to		
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

Life cycle inventory- VC 10: Adhesives from lupin

Stakeholder category	Category indicator	Sub indicator	Result	Score	Reference values (where relevant)
Farmers	Income diversification (BP)	Can the crop be integrated in the local farming practices?			Agricultural income statistics, lierature
	Social benefits (BP)	Do the workers have opportunities for additional financial support?	Relevance to European Green Deal policy areas		
Value chain actors	Technology development (C)	TRL	TRL: 6-7		
	System versatility (C)	Type of end product- relationship to logistics/ distribution channels			
	Market size (EU)	End product market capacity & demand projections			
Local community	Biodiversity (BP)	Crop traits and adaptation			
	Land acquisition, delocalisation and migration (LU)	Length of land occupancy			
	Access to natural resources (LU)	Use of marginal land for 1 tonne biomass			
	Local employment (all)	No. of direct Jobs	Jobs – paper		
	Contribution to rural economy (all)				
	Public commitment to sustainability (all)	Actions taken to support a sustainable development	Policies from S2Biom, literature, etc.		

7 References

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