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'Low ILUC-Risk' as a Sustainability Standard for Biofuels in the EU

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Abstract: Producers of biofuels for the EU market may use 'low ILUC-risk' certification as evidence that they have not deprived other economic sectors of feedstock material, and hence that indirect land use change (ILUC) emissions have been avoided. At present, the uptake of low ILUC-risk certification is limited to a handful of niche projects, as there is little commercial incentive for obtaining certification. This may be considered a missed opportunity, because low ILUC-risk farming methods offer a range of sustainability co-benefits beyond the mitigation of ILUC emissions. This paper examines the policy foundations of low ILUC-risk and develops policy recommendations that would aim to confer advantages to low ILUC-risk biofuels. Some weaknesses in the low ILUC-risk system's environmental safeguards are also highlighted.

Keywords: indirect land use change; low ILUC-risk; EU biofuel policy; RED Annex IX

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1. Introduction

1.1. Biofuel Policy in the EU

Biofuels were initially embraced in EU policy to reduce the transport sector's dependence on fossil fuels, increase energy security, and provide alternative revenue streams for farmers. It is now acknowledged that the rapid growth in biofuel consumption over the past one-and-a-half decades has precipitated a range of unintended negative impacts [1], including ecological damage from agricultural intensification and the distortion of food markets.

One major concern when it comes to biofuels is the phenomenon of 'indirect land use change' (ILUC), where elevated demand for agricultural products stimulates the expansion of farmland into previously unfarmed areas. Making way for crop planting by clearing and ploughing land poses risks to habitats, and may also lead to the release of carbon dioxide from vegetation and soils. ILUC emissions diminish and can even outweigh the supposed climate advantages of using biofuels in place of fossil fuels [2,3].

The main piece of EU legislation governing renewable energy usage is the Renewable Energy Directive (RED)—now in its third incarnation as 'RED III' [4]. The RED defines what forms of energy can be considered renewable, sets targets for the use of renewables in power generation and transport, and establishes safeguards to curtail unintended environmental consequences. As an EU directive, each RED iteration must be 'transposed' into national law by EU Member States, alongside or superseding existing national regulatory and policy frameworks. The final deadline for the transposition RED III is May 2025 [5]. At the time of writing, some Member States had transposed its predecessor RED II [6] but none had yet transposed the revised rules. The deadline for RED II transposition was 2021 [7], but many Member States have yet to complete their transposition of RED II's transport provisions [8]. Further introduction to the RED framework and its national implementations can be found in Appendices A.1 and A.2, respectively. (Appendices to this paper contain contextual and supporting information that can be read in parallel with the main text as required).

1.2. Aims of This Paper

The main objective of this paper is to provide recommendations for developing the RED's 'low ILUC-risk' concept (described in detail in Section 2.3). The underlying motivation, which this paper aims to justify, is the positive contribution that low ILUC-risk principles could make towards raising standards of sustainability for biofuels in the EU. In order to realise this potential, low ILUC-risk must be made more robust, and it must earn recognition beyond its present limited policy role.

Policy recommendations are devised based on three approaches: (i) the identification of weaknesses in current provisions and opportunities for enhancing environmental safeguards; (ii) the identification of new contexts in which the machinery of low ILUC-risk could be applied; and (iii) the identification of opportunities to enhance the viability of low ILUC-risk production models and enhance their value to biofuel industry players.

Recommendations are primarily aimed at the European Commission, which may continue to develop low ILUC-risk policy through the adoption of secondary legislation related to RED III. We also highlight overlaps with other policy areas (notably agriculture and carbon removals) that could be exploited in the future to create a layered value proposition for feedstock producers.

The global phenomenon of ILUC has been much studied and debated in the academic literature, but the same cannot be said of low ILUC-risk, which is a comparatively recent and niche concept. A number of on-ground studies have developed and tested agricultural production models consistent with low ILUC-risk principles (e.g., [9–13]), but ILUC-risk policy has received little attention in the academic literature (beyond a handful of studies considering the international trade implications of the high ILUC-risk concept [14,15]). This may be due in part to the relatively recent adoption—in 2021—of critical elements of the European Commission's implementation framework [16]; any findings before this time would have had to be either high-level or speculative (cf. the commentary in [17]).

This paper presents specific and actionable steps for creating an enabling policy environment for the uptake of low ILUC-risk certification. In so doing, it seeks to encourage the academic analysis and discussion of the potential use and implications of low ILUC-risk policy. Such discussion will span technical recommendations regarding the suitability and implementation of policy provisions (e.g., [18,19], which address, respectively, the policy recognition of suitable agricultural practices, and methodological issues with the calculation of quantitative yield baselines); it must at the same time build upon work intending to hold the production of biofuels for the EU market and beyond to high environmental standards (e.g., [20,21]).

1.3. Indirect Land Use Change

1.3.1. Direct and Indirect Emissions from Land Use Change

Indirect land use change (ILUC) is a critical contributor to the lifecycle greenhouse gas emissions arising from biofuel production and use. The RED's lifecycle analysis (LCA) methodology in Annex V of RED I/II/III employs the common accounting convention of treating biofuel combustion as if it produced zero carbon dioxide—the underlying assumption being that the carbon dioxide released from vehicle exhausts was itself recently absorbed from the atmosphere by growing plants. Biofuels' net emissions under RED accounting rules therefore come from other stages in the value chain: from the cultivation and harvesting of crops (running farm equipment, emissions from fertiliser, rotting and disposal of crop residues, etc.), from soil disturbance and the clearing of standing vegetation, from the industrial conversion of crop feedstocks into liquid fuel, and from the transport of feedstock and fuel. Calculating these kinds of 'direct' factors is relatively straightforward in the sense that they are directly connected to stages of the biofuel supply chain and production process.

More subtle are the 'indirect' effects that result from market-mediated competition for resources. As an example, consider a biogenic waste material generated in some industrial facility. If the waste stream is typically incinerated to produce heat and electricity for

the facility, then diverting it for the production of biofuels will force facility operators to seek replacement energy sources—e.g., fuel oil fed to boilers. What would be recorded as a climate 'win' for the biofuel producer may not change (indeed, may increase) the greenhouse gas emissions of the entire system.

In the EU, biofuel consumption has predominantly relied on the conversion of 'first generation' feedstocks; see the 'food and feed crops' series in Figure 1. In the context of the RED (RED II, Article 2(40), [6]), food and feed crops include crops that could be directly used in the food and feed sector, but are more generally main-harvest sugar-, starch-, or oil-rich crops (e.g., inedible oil from castor beans grown on agricultural land, which is used to make biodiesel). The definition of food and feed is set in relation to feedstock type rather than by direct reference to edibility because the production of inedible crop varieties may be interchangeable with the production of edible varieties. Put another way, taking agricultural land out of food production and devoting it to biofuel production could be considered equivalent to diverting the food itself.

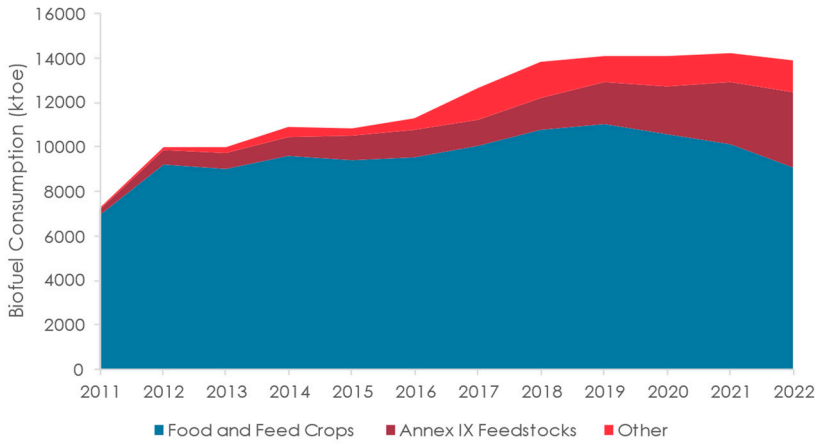

Figure 1. Biofuel consumption in the EU-27 in thousand tonnes of oil equivalent (ktoe). Note: The graph represents the physical energy content of fuels, meaning that Annex IX biofuels are 'single-counted'; see Section 1.3.2. Source: Eurostat, 'Use of renewables for transport', [22].

Since the RED's original incarnation, the policy has featured the following text (RED I, Recital 73, [23]):

> *"Land should not be converted for the production of biofuels if its carbon stock loss upon conversion could not, within a reasonable period, taking into account the urgency of tackling climate change, be compensated by the greenhouse gas emission saving resulting from the production of biofuels".*

The RED LCA methodology backs this up by including a requirement to estimate the land-based emissions that arise from agricultural activity as contributing to overall emissions. Provided the RED's land use rules are adhered to (see Appendix A.1), and the greenhouse gas emissions from land conversion are accurately estimated, such direct emissions from biofuel production are likely to be low.

The possibility remains, though, that indirect effects beyond the scope of the RED's LCA add significant land-based emissions to the officially reportable number. The ILUC phenomenon embodies the fact that diverting crop-based material away from its existing uses and into the transport sector has knock-on effects; such competition for the use of agricultural products and agricultural land stimulates farmers around the world to increase the area they farm, potentially resulting in the clearing of forests and shrubland, and the ploughing up of relatively carbon-rich soils that have previously lain undisturbed.

ILUC is a distributed global phenomenon that cannot be directly measured or linked to one specific cause. The indirect emissions associated with the use of a particular biofuel feedstock must instead be inferred using economic models of the global economy,

which consider a plethora of market effects, linking flows of material and money through different sectors. The complexity of the task coupled with the inevitable sensitivity to subjective modelling decisions results in a good deal of variation between published ILUC numbers [21].

Given the uncertainty and lack of convergence in ILUC modelling, the European Commission concluded that "the level of greenhouse gas emissions caused by indirect land use change cannot be unequivocally determined with the level of precision required to be included in the greenhouse gas emission calculation methodology" (RED II, Recital 81, [6]). ILUC estimates have no regulatory role in the EU; instead, the RED seeks to mitigate the problem of ILUC in the following four ways.

1.3.2. Controlling ILUC in the RED

The first RED provision that minimises ILUC is the cap on support for 'food and feed' crops. This measure was brought in with the 2015 'ILUC Directive' [24] (cf. Appendix A.1). In its current form, it limits the contribution of biofuels made from food and feed crops, with a ceiling of 7% of transport energy (the actual limit may be lower and varies by Member State). By forestalling the runaway expansion of food-based biofuel use, the crop cap limits the diversion of crops away from existing food and feed markets, and hence ILUC.

The second provision that minimises ILUC is the system of 'double counting' for certain privileged feedstocks that appear in Annex IX of RED II/III. These feedstocks comprise non-food crops, wastes, and residues that do not require the dedicated use of good agricultural land for their production, and do not obviously serve the demands of existing food and feed markets (examples include straw left over from harvests, shells of nuts, sewage, municipal solid waste, forestry residues like twigs and leaves, and used cooking oil). Annex IX feedstocks are considered to have lower sustainability risk than food and feed crops, and their use in the EU's biofuel sector is incentivised through double counting their energy content; a single megajoule (MJ) of physical Annex IX biofuel consumed in a Member State may be counted as contributing two MJ towards the Member State's RED targets (RED III, Article 27.2(c), [4]). In RED III, this applies for energy-based targets but not emissions-based targets (RED III, Article 27.2, [4]); see Appendix A.1 for a discussion of the two options. This creates an incentive for using Annex IX biofuels over conventional crop-based biofuels, and as seen in Figure 1, the share of Annex IX fuels has been steadily growing over time.

A third provision imposes a minimum greenhouse gas savings for each batch of biofuels entering the RED system: this 'safety buffer' reduces the risk that ILUC will counteract the supposed climate benefits of using biofuels. For biofuels produced in facilities that began operations in 2021 or later, the LCA score must show an emissions reduction of at least 65% with respect to the standard fossil fuel comparator of 94 gCO_2e/MJ (RED II, Article 29.10(c), [6]). So, even if a RED-eligible biofuel is associated with significant unacknowledged ILUC emissions (up to 61.1 gCO_2e/MJ for a biofuel just meeting the threshold), we can be reassured that the total emissions will not surpass the fossil fuel benchmark.

A fourth RED provision for mitigating ILUC is the introduction of the 'ILUC-risk' concept. This establishes a way for the EU to designate certain crop types as ineligible for RED incentives ('high ILUC-risk'), as well as a system for certifying crops that credibly avoid creating ILUC impacts ('low ILUC-risk').

A detailed description of high and low ILUC-risk, and what kinds of projects can be certified as low ILUC-risk, is provided in Section 2.3, after an outline of the research methodology used for this paper.

2. Materials and Methods

2.1. Policy Review

The research tasks for this paper can be summarised as reviewing the policy landscape relevant to the low ILUC-risk framework, identifying problems and missed opportunities, and formulating recommendations to address them. Figure 2 fleshes out this basic picture.

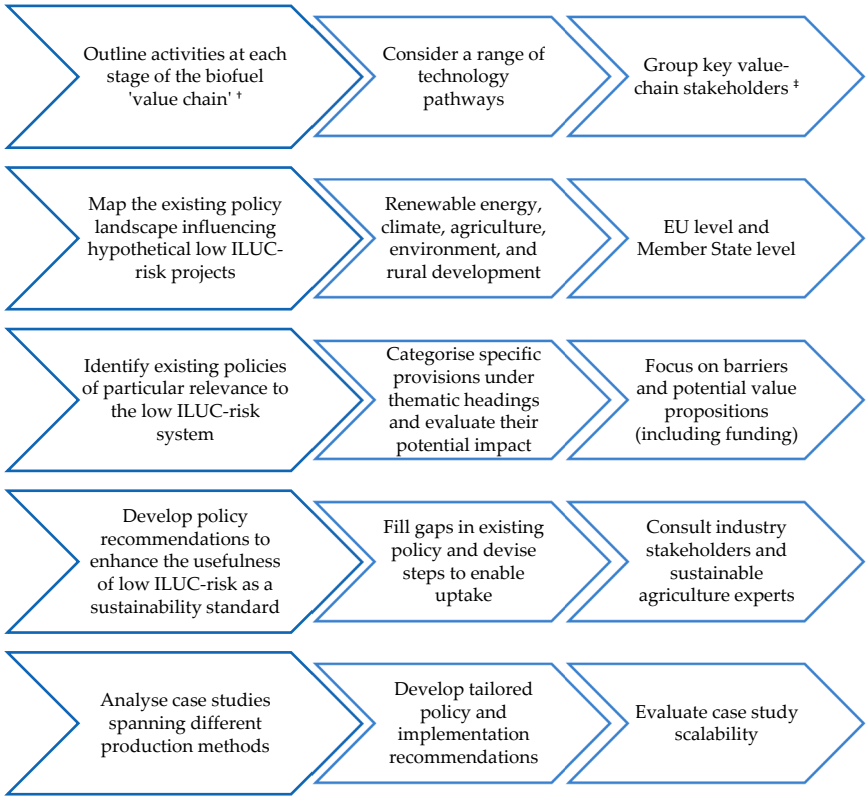

Figure 2. Outline of the policy analysis steps used for this analysis. Notes: † Biomass production, transport, fuel conversion, and fuel supply for a range of technologies/production pathways. ‡ Including policy institutions, implementation agencies, and economic operators.

The first row of Figure 2 concerns a preliminary exercise for setting the scope of the more substantial policy review covered by rows two and three. The policy review involved the compilation of a programme and legal texts with bearing on the low ILUC-risk system; at the EU level, these were primarily directives and regulations, but also some strategies and Commission communications (Appendix D lists the major ones considered). Each policy was characterised in terms of the type of legislation, major stakeholders involved, value-chain stages affected, and relevance to our research question. A more detailed follow-up review served to identify specific high-value or high-impact provisions within the legal texts. These were categorised qualitatively according to the scheme shown in Table 1, and disparate provisions were grouped under the thematic headings shown in Appendix C.

Table 1. Qualitive categories for the relevance of specific EU policy provisions to the low ILUC-risk system.

Marginal relevance	There is a contextual connection, but nothing linking the policy to low ILUC-risk production
Narrative relevance	Low ILUC-risk production could plausibly fit into the aspirational goals of a particular policy
Value relevance	The policy brings tangible and possibly quantifiable support—for example, funding eligibility
Barrier relevance	The policy may conflict with pursuit of low ILUC-risk production

Key findings from this phase of the analysis are presented in Section 3.1. For the purposes of this paper, it is unnecessary to report this foundational work and its outcomes in great detail, but interested readers may refer to the project report in ref. [25].

2.2. Formulation of Policy Recommendations

Moving on to the fourth row of Figure 2, based on the preceding policy landscaping work, we formulated provisional findings about the robustness and viability of low ILUC-risk certification. This work was undertaken in partnership with researchers from the Hungarian Institute for Agricultural Economics (AKI) and the Discovery Center. These were presented to representatives from the biofuel industry (specifically from UPM (United Paper Mills; Finland), Eni (Italy), and CIB (Consorzio Italiano Biogas; Italy)), and their feedback was incorporated into an updated draft. Agriculture experts from the UN Food and Agriculture Organisation (FAO) were also consulted on how the low ILUC-risk concept could fit into a broader sustainability narrative for EU agriculture.

The bulk of the results reported in Section 3 of this paper originate from this stage of the analysis. We present key conclusions, concentrating on policy recommendations that (i) could be plausibly enacted by policymakers in the near term, (ii) have a high degree of relevance to the low ILUC-risk system, and (iii) are candidates for boosting either the relevance, attractiveness, or integrity of the low ILUC-risk system. Issues and policy recommendations beyond the ones selected for this paper are discussed in the project report already cited [25] and a briefing note series [26].

The final row of Figure 2 concerns the application of policy findings to specific case studies of low ILUC-risk biofuel production models. The purpose here was to drill down on specific opportunities and challenges, to understand what the production models offered in terms of scalability, and to evaluate the relevance of our policy proposals to different real-world contexts. Since this paper is intended to focus on the more generic and structural policy issues discussed in the previous paragraph, we do not introduce the case studies here. The interested reader may consult a second project report [27] for more information and findings from this phase of the research.

2.3. High and Low ILUC-Risk

This section outlines in greater detail some of the key policy concepts and texts governing ILUC-risk in the EU.

2.3.1. High ILUC-Risk

As already mentioned, the 'ILUC-risk' concept comes in two different varieties: 'high ILUC-risk' and 'low ILUC-risk' (see Appendix A.2 for a note on correct use of terminology). While the focus of this paper is on the latter, we first introduce the high ILUC-risk concept to provide context. This will aid in the specification of low ILUC-risk in the next section.

High ILUC-risk crops are crops that have been implicated in agricultural expansion onto land with high carbon stocks, such as forests and wetlands. Biofuels based on high ILUC-risk crops are scheduled to be phased out in the EU by 2030. Some EU Member States have accelerated this schedule, eliminating incentives for high ILUC-risk crops with immediate effect; these include Austria, Denmark, France, Sweden [8], Germany ([28], §13(1)), and Belgium [29]). Palm and soybean are the two biofuel crop feedstocks that are most strongly connected with such expansion today—primarily in Southeast Asia and South America, respectively—though at the time of writing, the European Commission has only categorised palm as high ILUC-risk [30]. The status of other biofuel crops, including soy, is under review; a decision had been expected by September 2023 but has yet to be published [31,32].

The RED's general sustainability criteria (Article 29 of RED II and RED III, respectively [4,6]) exclude any biofuel feedstock produced on land that has been deforested or (in the case of wetlands and peatlands) drained since the year 2008. This restriction alone cannot, unfortunately, guarantee that biofuel consumption avoids driving destruction in such areas. For instance, it may be relatively straightforward for feedstock suppliers to swap a given batch of deforestation-linked palm or soy with a batch from a neighbouring farm that meets the RED criteria [33]. The land area that has been in agricultural production since before 2008 is large enough to supply a good deal of RED-compliant biofuel feedstock;

since material from non-compliant land areas is readily accepted in other markets with less strict sustainability governance, certification may simply shuffle material between markets without reducing the total amount of deforestation. The RED sustainability criteria should therefore be seen as a minimum standard to build upon.

The high ILUC-risk mechanism, in creating the ability to proscribe an entire crop category, prevents the shuffling of feedstock batches between sectors according to their provenance. It allows the EU biofuel sector to avoid creating extra demand for a commodity that is judged to be strongly implicated in environmental destruction.

2.3.2. Low ILUC-Risk

The 'low ILUC-risk' concept is the main focus of this paper. It was introduced in the 2015 update to the RED I [24] and then developed in RED II and two related Commission Delegated Acts ([6,16,34]). According to the most general definition, it designates crops that have been produced in a way that avoids the displacement of other land uses (RED II, Article 2(37), [6]). To be considered low ILUC-risk, a batch of biofuel feedstock must have been produced solely as a result of extra demand from the biofuel market—that is, it has not simply been diverted from the food sector. The low and high ILUC-risk frameworks are compared in Table 2.

Table 2. Key characteristics (simplified) of the high ILUC-risk and low ILUC-risk concepts formulated by the European Commission. Note: Information in this table is indicative only: the official definitions and language can be found in the European Commission's Delegated Regulation on ILUC-risk [34].

	High ILUC-Risk	**Low ILUC-Risk**
Simplified definition	Biofuel feedstocks which are linked with agricultural expansion into lands with high carbon stock (forests and wetlands)	Biofuel feedstocks produced in a way that minimises competition with other economic sectors (e.g., food and feed), and hence minimises ILUC
Scope	'High ILUC-risk' designation applies to entire feedstock classes (at present only palm oil)	'Low ILUC-risk' designation applies to batches of additional crop yield that originate from certified land
Policy impact	Under the RED, biofuels made from high ILUC-risk feedstocks are to be phased out of renewable energy targets by 2030; some Member States have adopted a faster phase-out schedule	At present, low ILUC-risk certification may exempt biofuels from the high ILUC-risk phase-out; this paper envisages a broader interpretation of the role of low ILUC-risk
Certification criteria	Over 10% of cropland expansion for the crop in question is into high carbon stock land; and expansion rate exceeds 1% per year	Certification requires land to undergo productivity-boosting 'additionality measures' that would not have been viable without RED incentives
Types of projects	All high ILUC-risk feedstocks are automatically subject to restrictions, unless exempted through low ILUC-risk certification	Projects which boost yields on existing farmland or introduce crop production onto unused/abandoned land
Other provisions	–	Certain certification criteria are waived for smallholder farmers (<2 ha)
Assessment	European Commission	Commission-approved certification bodies/voluntary schemes

In the language of a RED II Delegated Regulation (still applicable under RED III), feedstock from a given farm may be certified as low ILUC-risk if it is "additional feedstock obtained through additionality measures" ([34], Article 4.1(b)), where an 'additionality measure' is defined as:

> *"any improvement of agricultural practices leading, in a sustainable manner, to an increase in yields of food and feed crops on land that is already used for the cultivation of food and feed crops; and any action that enables the cultivation of food and feed crops on unused land, including abandoned land".*

(In this paper, ellipses in quotations may be dropped for ease of reading). Low ILUC-risk production systems may therefore be placed into three categories:

1. Growing a crop on land that is unused, has been abandoned, or has become degraded.
2. Increasing production of an existing crop though innovative farming techniques on in-use agricultural land.
3. Adding a productive 'intermediate' crop to an existing rotation on agricultural land.

(It should be noted that these categories are not explicitly defined in the EU legal text, and they are not universal in the literature on ILUC-risk: cf. [18,35] which distinguish five categories).

In order to qualify, a farm operator must be able to demonstrate, according to the criteria laid out in the Commission's Implementing Regulation [16], that the additionality measure they have chosen to apply is genuinely new and would not have been implemented anyway under a business-as-usual scenario. This condition having been satisfied, all crop yield that exceeds the baseline yield of the land in question can be considered additional, and hence certifiable as low ILUC-risk.

The RED conceives low ILUC-risk certification as a pathway for exempting high ILUC-risk biofuels from the EU's aforementioned phase-out. Thus, producers of palm-based biofuel batches that have qualified for low ILUC-risk status may continue to contribute to EU renewable energy targets, and hence reap RED-related policy value. However, the low ILUC-risk principle could be put to use in other contexts, too; there is nothing preventing the system from being applied to any crop used as a biofuel feedstock. This is a foundational premise of this paper that will have to bear some repetition (cf. point (ii) in Section 1.2); since low ILUC-risk offers a sustainability standard that has undergone years of development in the hands of European Commission officials, it is worth considering how it might be put to broader use. We will return to this in the 'Results' section (Section 3).

The 2022 Implementing Regulation finalised some of the key criteria and considerations for the low ILUC-risk certification process. Certification bodies like ISCC and RSB have now begun to develop and update their low ILUC-risk modules (e.g., [36,37]) and presumably train auditing partners in gathering the data required to assess applications. To the best of the authors' knowledge, these activities have yet to generate a significant number of certifications for biofuel feedstock producers and biofuel suppliers. Those companies that have been willing to trial low ILUC-risk certification have received broader interest from the research community and have participated in research exercises (such as [26,38]). The reasons for this, beyond the relative novelty of certification options, are a key motivation for this paper (cf. point (iii) in Section 1.2); we will return in Section 3 to the question of how to encourage the uptake of low ILUC-risk production methods through providing a clear policy-mediated value signal. In Appendix B.1, we further discuss issues surrounding scalability for these kinds of projects.

Finally, we have already indicated that the current formulation of environmental safeguards in the official low ILUC-risk legal texts leaves some room for improvement (cf. point (i) in Section 1.2). In Section 3.3.3, we highlight specific issues such as the control of invasiveness risks and hazards from agricultural intensification that may accompany low ILUC-risk projects on the ground if not designed with due care.

3. Results

3.1. EU Policy Interactions

The low ILUC-risk concept is fundamentally associated with energy policy; it offers, through the RED, a more sustainable basis to supply feedstock to the biofuel industry. However, low ILUC-risk farming systems also have characteristics considered desirable in other areas of agricultural and environmental policy (cf. [39]). While no single production model could encompass the diversity of possible low ILUC-risk projects, the expected benefits could include the accumulation of soil carbon, the provision of ground cover, the rehabilitation and utilisation of degraded land, and crop diversification. Commercialising low ILUC-risk production systems could therefore help in achieving goals beyond biofuel;

reciprocally, valorising 'low ILUC-risk' status in these other contexts could enhance the commercial viability of low ILUC-risk projects. At present, however, the low ILUC-risk concept per se is not explicitly recognised outside of energy policy.

The discussion in this section is mainly concerned with the policy dimensions. Some comments about the actual scalability of low ILUC-risk projects and the requirements for an effective certification system are provided in Appendix B.

3.1.1. Agriculture and Soil Policy

A prominent example of cross-over is in the context of the Common Agricultural Policy (CAP)—the primary funding mechanism for agriculture in the EU. This has immense influence on the bioenergy sector, through the incentives and limitations it places on different cropping systems and products. Take one example: the adoption of cover cropping and crop rotations is tied to CAP provisions; these conservation-oriented land management practices are consistent with those low ILUC-risk models where fast-growing cover crops are planted during fallow seasons, with the resulting biomass harvested for bioenergy uses. In the best-case scenario, well stewarded projects will benefit biodiversity and soil health, mitigate fertiliser runoff, and reduce pesticide use [39–41].

Similarly, both low ILUC-risk initiatives to boost productivity on agricultural land and activity on abandoned and severely degraded land have the potential to align with policy goals for rehabilitating and regenerating soils (as well as for invigorating and diversifying rural economies) [42]. The European Commission has registered concern about farmland deterioration and soil health in the EU, noting that 60–70% of EU soils are in a state of ongoing deterioration, costing tens of billions of euros per year ([43], Recitals 2 and 3). The Commission's Soil Strategy for 2030 [44], called for a broader understanding and application of sustainable soil management that will help to halt the EU's net soil degradation by 2030 and allow for the restoration of soil condition by 2050. Subsequently, Annex III of the Commission's Proposal for a Directive on Soil Monitoring and Resilience [43] listed the land management measures that Member States will be required to promote. These include locally appropriate crop rotations and cover cropping, as well as the use of deep-rooting perennials. Within this, there is certainly scope for integrating low-input bioenergy production.

From a farmer-oriented perspective, the CAP provides support for agricultural improvements undertaken in 'areas with natural and special constraints' (for example, steep inclines, stony soil, waterlogging, and adverse climate). This support is aimed at helping farmers who face particularly challenging circumstances to improve the productivity of land in danger of disuse. The production of low-maintenance and resilient bioenergy crops on such land may become eligible for low ILUC-risk certification if it satisfies RED's 'unused and abandoned land' definitions.

3.1.2. Restrictions on New Agricultural Projects

It is worth emphasising that the RED, the CAP, and other policy frameworks governing land and chemical use all contain certain restrictions on agricultural intensification and agricultural expansion (including into unused and low-productivity land). Both intensification and expansion are associated with environmental stress, and a major role of policy should be to ensure that only genuinely sustainable production models are incentivised. However, within EU policy there is no unified definition of 'sustainable agriculture' [45], and the standards and metrics used by different policy frameworks are sure to diverge on some points.

As an example of interlocking coverage, consider a hypothetical low ILUC-risk project in the EU that aims to prepare unused, non-protected land for biofuel feedstock production. From the perspective of purely ILUC mitigation, this satisfies the major requirements for additionality and avoids competition with food markets. The CAP, for its part, may well incentivise land conversion by providing area-based subsidies. Local laws aimed at safeguarding biodiversity and habitats, on the other hand, may require a more stringent

appraisal of the ecological services provided by the land, such that its use for agriculture is restricted even if it is not recognised at the EU level as a site of high biodiversity value. Additionally, if the project does end up producing feedstock that is eventually turned into biofuel, then the RED's stipulation that the lifecycle emissions savings surpass a certain minimum threshold will account for any carbon loss from soils following ploughing. Thus, though our hypothetical project may look promising from some perspectives, it may yet fail to deliver EU-approved 'sustainable' biofuel when all criteria are considered. Moreover, there is an even bigger question about the 'opportunity cost' of using land for biofuels rather than for reforestation or re-wilding. This is well outside the scope of the RED LCA, but it is worth bearing in mind that low ILUC-risk biofuel crops might not represent the most climate-efficient use of land. As with any complex policy issue, the uncontroversial conclusion here is that a greater level of inter-departmental coordination on protocols and key definitions would be welcome.

3.2. Policy Measures to Enhance the Attractiveness and Versatility of the Low ILUC-Risk System

This section highlights some specific challenges associated with the low ILUC-risk concept and its implementation, alongside actionable measures to overcome them. It should be understood that, notwithstanding the overlaps between policy areas noted in Section 3.1, low ILUC-risk was formulated as an energy policy tool; it would need to be refined and operationalised by policymakers in that context before being considered ready for broader recognition. As such, for the moment, the European Commission's Directorate General for Energy (DG ENER) would naturally take the leading role, and the proposals below are primarily for its consideration.

3.2.1. Definitional Clarification

Low ILUC-risk certification could be positioned as a high standard of biofuel sustainability in the EU, but this broad vision is in tension with its narrowly prescribed role in the RED (simply a mechanism to avoid high ILUC-risk classification). In this section, we contextualise some of the foundational policy language and suggest simple modifications to improve low ILUC-risk's relevance as a policy instrument.

The first point in this section concerns a technicality of the legal definition of low ILUC-risk. The introduction of intermediate crops suitable for bioenergy applications—such as cereals or oilseeds grown as cover crops—would be expected to form a core part of any hypothetical low ILUC-risk industry (see Point 3 in Section 2.3.2). However, definitions in the RED can be read as excluding the whole category of intermediate cropping. It is doubtful that this was the intention of the Commission, and the issue may have arisen because the low ILUC-risk concept was introduced as a basis for exempting fuel batches from the limitations placed on high ILUC-risk food and feed crops (Section 2.3.1).

The focus on food and feed crops is reflected in the definition of low ILUC-risk biofuels (RED II, Article 2(37), [6]):

> *"fuels, the feedstock of which was produced within schemes which avoid displacement effects of food and feed-crop based biofuels through improved agricultural practices".*

Food and feed crops are also central to the definition of the 'additionality measures', which must be applied for a fuel to be certifiable as low ILUC-risk—the definition was already quoted in Section 2.3.2 [34]. Now, RED II ([6], Article 2(40)) defines food and feed crops as

> *"starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land".*

With this, we are now in a position to observe the syllogism that low ILUC-risk certification applies to food and feed crops only. Intermediate crops as defined above (i.e., those that can be used for biofuels without triggering 'demand for additional land') are

not food and feed crops; therefore, intermediate crops are excluded from the low ILUC-risk system. While this definition of intermediate crops may have been intended to free them from the RED's cap on food and feed crops (see Section 1.3.2), in the context of low ILUC-risk, it creates a 'catch 22': if intermediate crops are produced without stimulating demand for more land, then they do not count as food or feed crops by definition, and thus fall outside the scope of low ILUC-risk certification—even though not stimulating demand for more land is exactly what low ILUC-risk is intended to certify. If, on the other hand, the crops are produced in a way that stimulates demand for land, then they are not intermediate crops per se; they default to being categorised as food and feed crops, and hence may be considered for low ILUC-risk certification. However, these food and feed crops would immediately fail the low ILUC-risk assessment precisely because using them in the biofuel sector would stimulate agricultural expansion. (The designation of low ILUC-risk crops as food and feed crops will also have implications for the new entries to the RED's Annex IX list of feedstocks, discussed in Section 3.2.2).

As a second point, the emphasis on food and feed crops alone also excludes cellulosic and ligno-cellulosic biomass crops from the low ILUC-risk system. These are already listed in the RED's Annex IX (see Section 1.3), but there is no reason that should in principle bar them from also being certified as low ILUC-risk. It is true that ligno-cellulosic crops are expected to have low (and possibly negative) emissions associated with land use change ([46], Section 3); RED II/III, for its part, assigns them an estimated ILUC factor of zero (RED II, Annex VIII, [6]). However, other studies have suggested that the ILUC emissions for crops such as switchgrass could be substantial [47], and many cellulosic biomass crop candidates have simply never been assessed for their global land use impact.

In any case, since biomass crops have been identified as good candidates for use in low ILUC-risk production models (such as in the reclamation of abandoned agricultural land), it makes sense to welcome them into the fold. The authors see no obvious downside if DG ENER were to revise its delegated acts with an extended definition of low ILUC-risk—for instance amending 'food and feed crops' to just 'crops' in the excerpts quoted above. Cellulosic biofuel producers would then have access to a pool of feedstock whose sustainability credentials have been audited and evidenced rather than just assumed.

3.2.2. Annex IX Integration as a Value Proposition

The lack of a clear value signal to incentivise low ILUC-risk biofuel production is a major barrier to interest from operators in the sector (discussed in Section 2.3.2). Here we suggest a way that the European Commission could raise the attractiveness of low ILUC-risk certification and production models at the EU level.

Biofuel feedstocks identified as having special sustainability characteristics are listed in Annex IX of the RED II/III. As explained in Section 1.3, many of these are wastes and residues from existing agricultural and forestry processes—such as straw, effluent from paper-making, and low-value wood products like waste bark and twigs. Ligno-cellulosic material (e.g., from biomass crops) is also listed.

Biofuels with Annex IX status are conferred advantages in EU fuel policy—through the 'double counting' mechanism, and through the binding of sub-targets for the inclusion of 'advanced' biofuels from Annex IX Part A. Context for these measures can be found in Appendix A.1. Feedstocks from Annex IX Part B—historically these have been waste oils and fats—are also double-counted, but their use is limited to 1.7% of transport fuel energy (physical energy, i.e., not double-counted). This cap is imposed partly because Part B feedstocks are used for mature biofuel production technologies, and the RED seeks to maintain a competitive incentive for Part A feedstocks, and partly because the consumption of Part B feedstocks has been associated with sustainability and fraud risks [1], which would be exacerbated by unlimited consumption. Member States are permitted to request a higher cap, and several have done so. For example, Finland's use of Annex IX Part B is uncapped, Cyprus and Malta have no obligation to impose a cap, Germany's cap is 1.9%, Hungary's 4%, Italy's 2.5%, and the Netherlands' 5% (all before double counting). Other

countries have no stated cap [8]. The cap for Part B biofuels notwithstanding, the carrots of double counting and Part A sub-targets make Annex-IX-based biofuels highly valuable (though it should be noted that this has not yet been sufficient to deliver a commercially viable industry for 'advanced' biofuels).

The European Commission may decide to add new feedstocks to the Annex IX list every two years, following a process whereby feedstock candidates are reviewed with respect to six considerations (RED II/III, Article 28.6). These include "the need to avoid negative impacts on the environment and biodiversity" and "the need to avoid creating an additional demand for land". Indeed, among the entries of the first (and so far, only) proposal put forward by the European Commission [48], many included conditions to forestall the significant diversion of useful resources away from the food and feed sector. The list of additions has now been finalised [49]; among the entries can be found requirements that feedstocks be unsuitable for the food and feed chain, and that the use of the material would not cause demand for additional land.

This is exactly the realm of the low ILUC-risk concept, and it is natural to posit that certification would provide a ready mechanism for a given farmer or biofuel producer to demonstrate that their batch of feedstock/fuel meets the conditions. It would be appropriate if DG ENER, on behalf of the Commission, were to specify that the relevant feedstocks may (or must) be certified as low ILUC-risk to qualify. This would make clear how the criteria for Annex IX eligibility can be satisfied in practice, with reference to an existing worked-through system; it would also avoid the need for fuel and feedstock suppliers to reinvent the wheel with each new Annex IX application by collating their own 'proof' of eligibility.

If low ILUC-risk were to become acceptable for supporting Annex IX status, then it would provide a clear value signal for producers to adopt low ILUC-risk practices. This would instantly solve a major problem highlighted above—namely that there is currently little motivation for biofuel suppliers to source certified feedstocks.

More specifically, the Annex IX additions concerning intermediate crops drew criticism from environmental stakeholders during the consultation phase [50,51]. These criticisms will only have been reinforced now that the final decision has been made, as aviation biofuels made from intermediate crops will be allowed to claim Annex IX Part A status (the original proposal was for all intermediate crop biofuels to be listed in Part B, which is capped). The text for Annex IX Part A Item (t) reads [49]:

> *"Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained, where not used for the production of biofuel for the aviation sector."*

The text for Annex IX Part B Item (f) is similar but applies to non-aviation fuels.

Notwithstanding the layers of conditionality, there are well-grounded fears that opening the door to intermediate crops will pose sustainability risks associated with the intensification and expansion of agricultural activity—e.g., ILUC and ecological impacts discussed in Section 3.3.3 below. The Commission has not provided clear instructions on how these risks are to be monitored and controlled. Unlike certain wastes and residues that are already listed in Annex IX, the potential for the global production of intermediate crops could be large—cf. [52], which frames intermediate crop feedstock as cheap and ready for rapid scale-up to plug shortfalls in fulfilment of fuel mandates (note that the definition of intermediate crops used is not exactly the same as the EU's, and so the results will not be completely transferrable to the EU policy context). Production will grow as regional crop varieties, production models, and supply chains develop. There are also concerns that an insufficiently rigorous screening regime could lead to instances of fraud—whereby material is spuriously labelled as being derived from 'intermediate crops' consistent with the RED definition (cf. [53], which discusses feedstock fraud in the RED).

Such issues could find at least a partial solution with the integration of low ILUC-risk into the Annex IX eligibility criteria. The certification of a batch of feedstock or biofuel would provide a stringent basis for producers to claim that they have avoided triggering demand for land, food market impacts, and ILUC.

3.2.3. Member State RED Implementations

A promising regulatory avenue for boosting the relevance of low ILUC-risk has already been established in RED II/III. Article 26.1 gives Member States considerable leeway to differentiate their treatment of biofuels on the basis of ILUC. The language used is [6]:

> *"Member States may set a lower limit and may distinguish, for the purposes of [the sustainability and greenhouse gas emissions criteria], between different biofuels produced from food and feed crops, taking into account best available evidence on indirect land-use change impact."*

Biofuels made from feedstocks that are generically associated with high levels of land use change may therefore be subjected to extra scrutiny or more stringent thresholds, at the discretion of each Member State. The RED gives the example of limiting the contribution of biofuels made from oil crops, which are particularly prone to ILUC effects; some Member States have already used this freedom to curtail the use of soy-based biofuel, and to accelerate the phase-out of palm oil (cf. [54]). In principle, a Member State may decide to deploy other mechanisms to limit the attractiveness and use of ILUC-linked crops in the transport sectors. Since EU law has established low ILUC-risk certification as demonstrating that a feedstock has been produced without ILUC, such certification offers another tool that Member States can use to distinguish biofuel feedstocks with different sustainability credentials.

Options for differentiating between types of crop-based biofuels include multiple counting their contribution to RED targets to boost their attractiveness, enacting government procurement rules that favour the use of some biofuel types over others, and eligibility for subsidies at the feedstock production or the fuel conversion stages [21]. There are also some options that are unlikely to find a receptive audience at the European Commission. For instance, Member States are likely to be discouraged from adopting a hybrid LCA that includes ILUC emission estimates, for the reasons covered in Section 1.3.1.

The most obvious route for Member States would follow the mechanisms and precedents laid out in the RED: allow crop-based biofuels certified as-low ILUC-risk to be multiple-counted towards renewable energy targets. This would give low ILUC-risk biofuels an edge over conventional first-generation biofuels; just how much of an edge will depend on the chosen multiplication factor. To provide a compelling stimulus to low ILUC-risk production, the factor would have to be somewhat greater than 1. However, one would want to preserve Annex IX Part A feedstocks' place at the top of the biofuel hierarchy due to the upsides of using wastes and residues and the potential downsides of relying on crop-based biofuels (even if certified as low ILUC-risk—see Section 3.3.3). Under the current system, this would necessitate a factor somewhat less than 2. The appropriate government department would have to undertake a careful analysis to justify any given choice of intermediate value—too low, and low ILUC-risk may fail to be an attractive compliance option at scale; too high, and it could outcompete more sustainable waste-and-residue-based options. This analysis would presumably have to estimate the value boost that multiple counting would confer on eligible feedstocks, as well as the production costs of low ILUC-risk feedstocks compared to conventional first-generation and Annex IX feedstocks. Countries within the EU that choose to ascribe a higher factor would act as a draw for certified low ILUC-risk material from the EU and beyond.

Implementing multiple counting would be most straightforward for Member States that use an energy-based fuel quota (refer to Appendix A.1 for a discussion of energy-based and emissions-based systems). RED III makes no provision for using multiple counting for systems that have adopted emissions-based targets ([4], Article 27.2); however, a precedent for doing so exists in Germany, and we are not aware of the Commission having initiated

any infraction proceeding in relation to this particular point (cf. [55]). Under the German system, each fuel supplier is obligated to meet an annual target for reducing the average greenhouse gas intensity of their fuels (Federal Immission Control Act, §37a(4), [28]). The greenhouse gas intensity is calculated as an average over all fuels that the supplier brings to market, weighted in proportion to the amount of fuel energy supplied. For multiple-counted fuels, the energy content is multiplied by the relevant factor before the average is taken. Consider a hypothetical fuel supplier that reports two batches of fuel: 1 MJ of double-counted fuel, with an emissions intensity of 10 gCO_2e/MJ, and 8 MJ of single-counted fuel with an emissions intensity of 50 gCO_2e/MJ. The calculation will assume 10 MJ of fuel overall, with an average emissions intensity of 42 gCO_2e/MJ. Thus, the carbon intensities of multiple-counted fuels are given an outsized influence on average.

Under a system like Germany's, a batch of biofuel that is both certified as low ILUC-risk and certified to have a relatively low emissions score could be marketed at a premium; this would allow low ILUC-risk biofuels to outcompete conventional food crop biofuels even if they have the same greenhouse gas intensity, raising the profile of improved farming methods that sustainably increase productivity.

However, multiple counting is not without its detractors, as more multiple-counted material means less material overall—and hence lower nominal emissions savings. This holds for both energy- and emissions-based targets. Therefore, in a scenario where large volumes of multiple-counted low ILUC-risk material become available, national policy-makers may be urged to raise the level of renewable energy targets to compensate. At the same time, they would have to decide the extent to which they are prepared to allow low ILUC-risk biofuels, which boast only modest direct emissions savings (but greater guarantees of low indirect emissions), to outcompete biofuels with lower direct emissions but potentially high indirect emissions. Note that the greenhouse gas emissions savings threshold is not affected by the multipliers, meaning that the low ILUC-risk biofuels would have to satisfy the same cutoff as regular biofuels in terms of their direct emissions.

3.3. Policy Measures to Strengthen Low ILUC-Risk as a Sustainability Standard

Section 3.2 showcases opportunities for galvanising a broader interest in low ILUC-risk—the underlying premise being that low ILUC-risk could provide a platform for certifying more genuinely sustainable biofuel feedstocks. However, there remain some weaknesses in how the system is currently realised.

3.3.1. Uncertainty in Crediting Additional Yield

In this section, we consider how the realities of agricultural production systems—in particular the annual yield variability, which is outside the control of the farmer—may impact the delivery of low ILUC-risk projects.

Recall from Section 2.3.2 that central to the low ILUC-risk concept is the principle of 'additionality'—low ILUC-risk feedstock must be produced over and above 'business-as-usual' in order to avoid diverting material from existing uses. There are two layers to unpack here. First, for a plot of land on a farm to gain low ILUC-risk certification, new yield-boosting practices ('additionality measures') must be implemented that would not have happened anyway. Such practices could involve improved sowing, irrigating, or harvesting techniques, or introducing a new intermediate crop that grows during the off-season. Second, assuming this intervention is successful, only the new, extra part of the yield from the plot in question should be considered additional. The achieved yield must therefore be compared with a counterfactual 'baseline'.

The simplest version of this baseline would be the average historical crop yield based on data from before the additionality measure was implemented. However, this may not be accurate in the longer term, as crop yields are anyway growing over time due to other forces (cf. [56,57]), and spuriously certifying this background growth as low ILUC-risk would run completely counter to low ILUC-risk principles.

In the case of new cultivation on unused and abandoned land, the baseline is set to zero, and following certification, all the material produced from the land may be considered low ILUC-risk. Here, it is straightforward to identify the 'true' quantity of low ILUC-risk material, but this is not the case for projects which seek to boost yields on existing farmland; here, the producer of a given crop on a given plot of land must construct forward-looking baselines by combining the average historical yield with the global average yield growth trajectory for the crop. The baseline is hence set from the time that low ILUC-risk status is conferred on an economic operator, and yield above the baseline in subsequent years can be certified as low ILUC-risk feedstock. Fluctuations in achieved yields, compared with the fixed baseline, mean that the volume of certifiable feedstock is highly uncertain year to year.

Previous work has shown that, at a statistical level, the RED's baselining methodology will tend to systematically favour some regions and disadvantage others, depending on their background trends of yield growth [19]. In regions with low yield growth (relative to the global average), farmers experience a 'headwind' and struggle to register certifiably additional production even when there have been genuine improvements to yields. Conversely, farmers in regions where background trends are already delivering high yield growth experience a 'tailwind' and could hypothetically claim low ILUC-risk production even if they have not actually delivered any additional yield improvement.

Several factors contribute to head/tailwinds. There are regional changes that are largely outside the control of individual farmers, for example, changing climatic and ecological conditions in the region (e.g., warmer weather, decreased precipitation, pest prevalence); and there are more localised innovations and improvements actively undertaken by individual farmers to improve yields, efficiency, and reliability. Such farmer-driven measures do not occur in a vacuum, of course, and they will generally be facilitated (or hindered) by evolving conditions on the ground, like the availability of new seed varieties and technology solutions, or access to new markets. So, the distinction between the two categories can become a little blurred. In any case, we may expect to observe a trend of gradually rising yields when aggregating over all farms, even though individual farmers themselves experience something more like a discrete step up, with relatively flat average yields before and after the intervention. From this perspective, comparing farmers' yields with a steadily rising global average appears to miss the reality of implementing on-farm changes; however, on a large-scale statistical level it is a defensible approach if the goal is to avoid excessive spurious material being certified as low ILUC-risk.

A second bias in the RED methodology systematically over-credits the amount of additional material on average, through a 'ratchet' effect. Weather-driven yield fluctuations above the baseline are to be treated as additional, while fluctuations below the baseline are ignored. This means that even a project that fails to deliver any genuine additional feedstock will be guaranteed to generate spurious additional material in those years where the weather has been favourable [19].

The biases outlined here could be mitigated to some extent by modest changes to the RED methodology for baselining, and for crediting the production of low ILUC-risk material [19]. Region-specific headwinds and tailwinds could be mitigated by the choice of region-specific baselines, for which the necessary data already exist (e.g., the productivity datasets reported to the FAO [57]). The crediting of spurious material through tailwinds and the ratchet effect (i.e., allowing ILUC-linked biofuel to masquerade as ILUC-free) could be mitigated to some extent by imposing discounts on yields that exceed the baseline or the farmer's own yield projections by some set threshold—this would have the effect of containing some of the larger over-crediting effects.

3.3.2. De-Risking Returns

The possibility of over-crediting notwithstanding, yield variation poses a challenge for farmers who may understandably be reluctant to double-down on a reward system with unpredictable payoffs. To become certified as low ILUC-risk, producers must implement

improved farming practices that go beyond business-as-usual operations and undergo an arduous certification process. They are unlikely to embark on such an undertaking without good prospects of financial return. Part of the answer here is to provide a decent value signal for farmers to invest in low ILUC-risk feedstock production, for instance through inclusion in Annex IX (Section 3.2.2), and not to tolerate systematic over-crediting. But even then, the amount of certifiable feedstock that a farmer produces in a given year can dip below the baseline, according to the caprices of the weather.

This points to a fundamental issue with 'results-based' crediting approaches for yield improvement projects. A results-based system is one where operators are rewarded for demonstrating that they have delivered some target outcome, but when the target outcome is sensitive to factors outside of the operator's control, the system risks undermining its own aims by deterring participation and therefore missing the opportunity to foster and support improved practices. Moreover, some of the measures that could be undertaken in the name of low ILUC-risk production require high up-front expenditures that pay off over a long time—examples include buying machinery to help with harvesting new crop varieties or preparing poor-quality land for cultivation through de-stoning or terracing. Large initial outlays could represent a significant barrier to prospective low ILUC-risk producers, especially in light of uncertain returns.

These factors may prompt us to consider hybrid approaches that combine 'results-based' and 'action-based' crediting. In a hybrid system, operators are rewarded in part for demonstrating that they have implemented eligible productivity-boosting measures, and then in part for demonstrating improved outcomes arising from those measures [19,20]. In the context of the results-based low ILUC-risk system, the CAP could act as a natural action-based complement, and indeed it may already fulfil this role to some extent, as many of the 'additionality measures' that qualify a farm project for low ILUC-risk certification are already encouraged by the CAP's greening initiatives [58]. In principle, coordination between the RED and the CAP could be formalised by the Commission's Directorate General for Agriculture and Rural Development (DG AGRI), through explicit recognition of the low ILUC-risk system. Certification could then be used by farmers to claim special support targeted towards the improved production methods that form the basis for low ILUC-risk projects.

3.3.3. Environmental Safeguards

In this section, we consider some unintended environmental impacts that may be associated with growing biofuel feedstocks, stemming from the ecological appropriateness of energy crops. These issues are likely to be most pronounced for low ILUC-risk projects involving cultivation on formerly unused land and in-between main harvests.

Minimum sustainability provisions in the RED prohibit the crediting of biofuels made from crops sourced from certain protected land types, like forests and biodiverse grasslands ([4], Article 29). As we have seen, the low ILUC-risk system promotes the use of bioenergy crops that can thrive even when growing conditions are poor (in-between main seasons, or on abandoned, unused, and severely degraded land). Candidate crops, both perennial and annual, have been identified that could fill these niches, and many of these are potentially beneficial to soil cover and structure, water retention, pollution control, phytoremediation, and local biodiversity [59–61]. However, such benefits are not guaranteed. A shift from vegetated unused and abandoned to rotational arable lands will generally diminish floristic diversity, insect and pollinator populations, and shelter and breeding opportunities for wild animals (as can be inferred, for example, from [62,63]; cf. [39]). Such impacts are typically hard to ascertain for individual projects on short time scales [64], and there are, conversely, some limited opportunities for active agricultural land management to enhance rather than detract from ecosystem services and biodiversity [65]. Nevertheless, research has pointed out that abandoned agricultural land takes time to recover its soil carbon and biodiversity [66,67]; land that has been abandoned for longer periods of time will tend

to have progressed further in its regeneration stages, and hence have more to lose from renewed disruption.

Energy crops that are optimised for fast growth in adverse conditions may, depending on locale, pose invasiveness risks and impact biodiversity by displacing native plants—a classic example of this is *Arundo donax*, which is identified as invasive outside of its natural habitat [68,69]. Unused and abandoned lands that have developed niche ecological communities may be particularly vulnerable to such disruption. Moreover, the establishment of productive crops requiring irrigation may have the effect of diverting potentially scarce green and blue water resources away from the local environment.

If low ILUC-risk crops such as the intermediate crops discussed in Section 3.2.2 gain policy value in the future, then the use of yield-boosting fertilisers and plant protection products (like pesticides) is likely to increase. Such intensification has the potential to disrupt soil and habitats [70,71], including through the introduction of additional (i.e., low ILUC-risk) stages of crop cultivation and harvesting in the off-season or on formerly untouched land. The debates surrounding these issues are well rehearsed in the context of industrial agricultural systems; the specific case of biofuel production simply adds more of the same.

The ecological safeguards required by the RED and certification bodies' low ILUC-risk assessment standards touch upon many of the major problem areas associated with agriculture, but there remains much room for improvement [35,72,73]. Taking the example of biodiversity, the RED prohibits the use of highly biodiverse lands for the production of biofuel feedstock (RED II, Article 29, [6]), but impacts on 'moderately' biodiverse lands will fly under the radar. Meanwhile, the Commission Implementing Regulation on voluntary schemes stipulates that low ILUC-risk projects should not compromise landscape diversity and pollinator populations ([16], Annex VIII), but does not compel operators to provide evidence. What measures operators could take to fulfil the requirements are therefore up to the certification bodies to decide; as far as the authors are aware, there are no firm guidelines on this in any low ILUC-risk certification documents.

In short, the existing ecological safeguards in low ILUC-risk policy may allay some (but certainly not all) of the broader environmental concerns mentioned above. There is room for the European Commission's DG AGRI to support field trials for the development of sustainable agrotechnical systems, with a focus on those applicable in unused, degraded, and abandoned lands [59]. Once production models have been demonstrated to avoid compromising long-term environmental and agricultural health, unambiguous conditions could be developed so that biofuel policy does not inadvertently encourage unsustainable practices.

3.3.4. Subjectivity in Implementation

In this section, we consider more generally the task of implementing a workable certification scheme, and how protocols affecting low ILUC-risk projects may have to adapt to realities on the ground. General comments on the effectiveness and usability of sustainability certification schemes can be found in Appendix B.2.

First, some background about the certification process. Auditors sent to conduct assessments of applicant farms and farm groups are, in an ideal world, selected to have expertise in local farming practices. Nuanced, contextual judgement can help to determine whether applicants are complying with the spirit of the certification rules; for example, a farmer may claim that the 'additionality measure' that they have implemented is not common practice in their region, and that it goes beyond business-as-usual. Assessing the barriers to the adoption of the new practice for the low ILUC-risk additionality test benefits from local insight.

The task of crafting policy texts that strike the right balance between helpful guidance in decision-making and responsivity to unpredictable situations is tricky. We anticipate that some of the assessment methodologies laid out in the Commission's Implementing Regulation on voluntary schemes [16] could be seen as offering insufficient guidance in

decision-making, placing inappropriate demands on the ingenuity of applicant and auditor alike, and leading to inconsistent outcomes. In other places, conversely, the Commission errs towards the prescriptive or generic, producing potentially arbitrary results from the perspective of low ILUC-risk applicants.

As an example of the first problem (under-prescriptiveness), we note that low ILUC-risk certification candidates are required to submit a 'management plan' that includes, among other things, a forecast of the expected yield impact of their additionality measure. In the case of novel agricultural practices, it may be exceedingly difficult for a farmer to accurately predict the impact on yield in their specific context. Individual applicants will often lack the capacity to present detailed literature reviews or undertake original agricultural modelling, and therefore there is a risk that the predictions included in management plans will bring limited actual value, bought at the expense of farmers' and farmer groups' time and mystification. The European Commission may be able to bring a degree of consistency to management plans by collating a set of credible results on key practices to be used as a reference by applicants. This could be achieved, for example, through reporting by the Joint Research Centre.

The second problem (over-prescriptiveness) can be illustrated by an instance of strict, quantitative methodology implying a degree of objectivity that may not be warranted by realities on the ground. The RED allows biofuel producers to claim credit for negative emissions achieved when soil carbon stocks increase during the feedstock growth phase; the contribution to fuel lifecycle emissions is called 'e_{sca}' ([6], Annex V). Low ILUC-risk production models overlap with farming practices that are likely to build soil carbon [73,74]—for example, the introduction of deep-rooting perennials to abandoned, degraded agricultural lands can be used to stabilise and enrich soils. The authors would anticipate that, should the low ILUC-risk system gain traction for certifying biofuel production, it will frequently be 'stacked' with soil carbon crediting.

The Implementing Regulation ([16], Annex V) details the RED procedure for estimating e_{sca}. This uses a combination of in situ sampling and modelling, attempting to balance accuracy on one hand with complexity, laboriousness, and cost on the other. For instance, flexibility is given to adjust on-farm sampling density according to the heterogeneity of readings; however, there are no indicative thresholds or guidelines for making adjustments, meaning that it is up to certification bodies and/or the surveyor to interpret the legislation on the fly. Moreover, it is unclear whether the Implementing Regulation measurement strategy will provide a good estimate of soil carbon stocks. The instructions are to take samples from the top 30 cm of soil, but the carbon stock in this layer is highly dynamic and prone to changes due to weather and/or shifting management practices [75]. Crediting e_{sca} based on topsoil readings will give precise but unreliable results, and even a 'good' result does not guarantee long-lived carbon sequestration or long-lived soil health improvements. There is scope for the Commission to develop a protocol for assessing soil carbon based on deeper sampling.

Under RED II's energy-based framework, the inclusion of e_{sca} would have enabled some crop-based biofuels to surpass the emissions reduction threshold and become eligible for RED incentives. Now that RED III has opened the door to emissions-based targets, there are further opportunities for biofuel producers to capitalise on e_{sca}. It would be appropriate for the Commission to consider what further kinds of safeguards could ensure that crop–biofuel projects are not unfairly boosted through flimsy claims of soil carbon sequestration, while also providing guidance to surveyors on how to deal with heterogeneity [75].

4. Discussion

This paper has sought to develop an understanding of the EU's 'low ILUC-risk' framework and evaluate its potential as a sustainability standard for crop-based biofuel feedstocks.

The investigation of low ILUC-risk covered three areas: (i) shortcomings in its existing environmental safeguards; (ii) opportunities to broaden its applicability; and (iii) options for improving the attractiveness of certification. In combination, these aim to increase the

viability of sustainable cropping models linked to low ILUC-risk principles and practices and enhance their value to a biofuel industry that is currently reliant to a large degree on conventionally grown crop-based feedstocks.

In the initial phase of research, the EU policy landscape surrounding biofuels in general and the low ILUC-risk framework in particular was mapped and characterised. From this foundation, it was possible to identify challenges and opportunities in line with the three research areas above, and refine these through stakeholder consultations and through the consideration of low ILUC-risk value chain case studies.

The main results of this study are presented as a policy discussion and recommendations for the consideration of relevant policymakers, namely the European Commission and EU Member States. These cover the following (in order of appearance in the 'Results' section (Section 3)):

- Recognition of the institutional and policy overlaps between energy, agriculture, environment, and climate goals in the context of low ILUC-risk production models (Section 3.1);
- Review of potential inconsistencies identified in legislative texts (Section 3.2.1);
- Broadening of the scope of low ILUC-risk certification to apply to a larger range of crop types (Section 3.2.1);
- Provision of a definite value signal to drive uptake, for instance through the use of low ILUC-risk certification in connection with criteria for the Renewable Energy Directive's Annex IX (Section 3.2.2);
- Integration with Member States' renewable energy policies (Section 3.2.3);
- Boosting the robustness of the current feedstock-crediting methodology in light of yield variability (Section 3.3.1);
- Consideration of a hybrid value proposition for feedstock producers to deliver greater certainty in returns (Section 3.3.2);
- Evaluation of gaps in environmental safeguards when it comes to the introduction of novel cropping projects and techniques (Section 3.3.3);
- Refinement of guidance provisions for both low ILUC-risk candidates and certifiers, in the interest of efficiency and reproducibility (Section 3.3.4).

These recommendations represent a contribution to the modest existing literature on the technicalities of low ILUC-risk policy. It is hoped that future work will continue to investigate the strengthening of biofuel sustainability standards, offer solutions to potential blind spots in the policy framework, and bridge the divide between policy principles and the realities experienced by stakeholders on the ground. Aside from this, the demonstration of financially viable production models adhering to low ILUC-risk principles will be critical to the future uptake of low ILUC-risk certification.

5. Conclusions

The Renewable Energy Directive (RED)'s 'low ILUC-risk' concept was developed to certify biofuels produced in a way that avoids diverting material from the food and other markets. This provides assurance that the consumption of said biofuels (i) does not raise food prices, (ii) does not stimulate additional demand for agricultural land, and (iii) does not cause 'ILUC' (indirect land use change) emissions.

Low ILUC-risk feedstock production could play a positive role in the future of EU biofuels by following a stringent sustainability standard that should obviate some of the deep concerns surrounding first-generation biofuels. Through the use of feedstock certified as low ILUC-risk, industry players gain a pathway for supplying biofuel with demonstrably higher sustainability credentials than uncertified first-generation biofuels (see Appendix B.2 for some considerations regarding stringency in low ILUC-risk certification schemes).

The challenge with low ILUC-risk certification is proving that a given batch of crop-based feedstock is genuinely 'additional'—that is, surplus to a counter-factual baseline of production. Generically, there are three types of projects that can be certified: ones growing crops on unused or abandoned land, ones improving the yields of an existing crop

rotation, or ones boosting the productivity of a given land area through the addition of an intermediate bio-energy crop into the rotation. Once a land area has demonstrated that genuinely new measures have been taken to produce additional crop material, it may be certified as low ILUC-risk, after which point crop yields that exceed the baseline level of production can enter the biofuel value chain as low ILUC-risk feedstock.

As with all biofuel-related policy, low ILUC-risk overlaps several sectors—energy, climate, agriculture, environment, and rural affairs. At present, there is scant incentive for farmers and biofuel producers to participate in the low ILUC-risk system, and at the time of writing, only a handful of specialised projects have been trialled against its requirements.

There is limited academic literature engaging with the minutiae of low ILUC-risk policy. This paper has sought to identify and propose remedies for some weaknesses of the low ILUC-risk framework and propose measures to enhance its relevance and usefulness to the biofuel industry by providing a value proposition that could benefit players beyond producers of palm oil biofuels. For example, one of the options proposed in this paper to drive the uptake of low ILUC-risk would be to require low ILUC-risk as an eligibility criterion for crop-based feedstocks to the RED's Annex IX—the list of 'most sustainable' biofuel feedstocks, which are accorded special incentives. This could be executed at the EU level through action by the European Commission's Directorate General for Energy (DG ENER); it could also be carried out unilaterally by EU Member States in their national RED transpositions. The RED's Article 28.1 explicitly affords Member States a degree of autonomy in their treatment of biofuels' ILUC impacts, and this paper has suggested one way that this power could be used to give low ILUC-risk production models a competitive advantage over the conventional production of biofuel feedstocks, using a 'multiple counting' mechanism.

The measures required to gain low ILUC-risk certification may be neither simple nor cheap. We may see farmers and farmer groups calling for financial or administrative support to update their existing practices. For EU-based projects, there is scope for more explicit co-recognition of sustainable agricultural practices that meet Common Agricultural Policy (CAP) goals. This would require a considerable level of coordination within the Commission, between DG ENER and the agriculture-focussed DG AGRI. Arguably, a more widespread uptake of low ILUC-risk (requiring a viable value proposition from energy policymakers) would be needed before overlaps with agricultural policy can be exploited.

As a final comment, while low ILUC-risk offers some cross-sector synergies, there are also trade-offs between competing social and policy goals. Low ILUC-risk certification, for all its merits, does not solve the tension between using land for agriculture versus the creation of protected natural areas, say; or the tension between the intensified use of agricultural inputs to boost yields on one hand, versus the need to minimise environmental pollution, as well as conserve resources such as water and soil carbon, on the other. It is fair to expect that expanded and/or intensified agricultural production, even under the banner of the low ILUC-risk concept, will have a variety of impacts on the natural world. The adoption of a coherent approach to land use that maximises environmental and social benefits must therefore be a matter of ongoing evaluation.

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Appendix A. The EU Renewable Energy Directive

Appendix A.1. A History of the RED

The Renewable Energy Directive (RED) is the primary pillar of alternative fuel policy in the EU. It establishes EU-wide goals for the use of renewable fuels such as biofuels, as well as criteria that those fuels must meet in order to be acceptable. Here we give a brief overview of the RED's transport provisions in order to situate readers unfamiliar with the history of renewable fuel policy in the EU. More technical detail can be found in [76,77].

As a preliminary remark, EU directives such as the RED do not themselves create legal obligations for economic operators; instead, the RED compels Member States to place legal obligations on fuel suppliers that will ensure targets are met. This means that not every element of the RED will necessarily appear in Member State transpositions.

The first RED, adopted in 2009 [23], set a 10% target for the use of renewable energy in transport in the EU (this was to be calculated as renewable energy used in all transport modes, divided by all energy used in the road and rail sectors). The RED established a mechanism to double count biofuels produced from wastes, residues, and (ligno-)cellulosic material, and established minimum standards of sustainability for renewable fuels—for instance, feedstocks could not be sourced from forests or highly biodiverse lands (unless it could be demonstrated that no harm was done), and all biofuels had to satisfy a lifecycle emissions threshold. However, there was no provision to control ILUC until the adoption of the 2015 "ILUC Directive"; this limited the use of 'food and feed' crops for biofuels [24] and restricted the scope for double counting to a defined list of eligible materials (cf. the discussion of 'Annex IX' in Sections 1.3.2 and 3.2.2 of the main text).

The RED was updated to 'RED II' in 2018 [6]. The 2030 target for renewable energy use in the transport sector was set to 14%, with a 3.5% sub-target for the use of biofuels made from feedstocks appearing in Annex IX Part A. Because of double counting, the latter was only a 1.75% target on a physical energy basis, and the overall 14% target was therefore at most a 12.25% target. Renewable electricity supplied to road vehicles was given a 4× multiplier, and to rail a 1.5× multiplier. These incentives for using Annex IX biofuels and renewable electricity reduces demand and competition for agricultural land.

RED II also updated the sustainable land use criteria for biofuels. The methodology for calculating an alternative fuel's lifecycle greenhouse gas emissions covered many stages of fuel production (transport, refining, soil carbon accumulation for crop-based biofuels, etc.), and it excluded emissions arising from indirect effects such as ILUC. Instead, ILUC was to be controlled through the mechanisms outlined in detail in Section 1.3 of the main text.

The next iteration, 'RED III', entered into force in November 2023 [4]. Member States must transpose new provisions into law by May 2025 [5]. The new transport targets are based on energy supplied for all transport modes, including off-road, maritime, and aviation [77]. Another structural shift was the inclusion of a new option for an emissions-based target: in 2030, either 29% of all transport energy should be renewable, or its greenhouse gas intensity should be reduced by 14.5% (compared to a fossil baseline of 94 gCO_2e/MJ). The former energy-based target includes multipliers, while the latter emissions-based target does not, and a move to the latter system may shuffle the hierarchy of fuels to some extent. For example, biodiesel made from waste oil may receive double the incentive offered to crop-based biodiesel under the energy-based system, but may receive the same incentive as crop-based biofuels with low lifecycle greenhouse gas emissions under the emissions-based

system. Generally, the new targets reflect increased ambition compared to RED II. The cap on the use of food and feed crops (see Section 1.3.2) remains the same in percentage terms, but because RED III encompasses a larger fuel pool than RED II, the absolute amount of this kind of biofuel that can be supplied has risen.

Appendix A.2. RED Implementation

The national laws introduced to fulfil the requirements of directive transposition will place obligations on economic operators within the country. In the case of the RED, a country may require fuel suppliers operating within its borders to, for example, pay a differentiated tax depending on the type of fuel supplied (e.g., Norway: see [78]; Norway is part of the European Economic Area (EEA), which has adopted RED I), to provide a given proportion of renewable energy to the transport pool (e.g., the Netherlands: see [79]), or to demonstrate that the average emissions intensity of fuels they bring to the market meets an annually declining threshold (e.g., Germany and Sweden: see [28,80]). A Member State must satisfy the European Commission that the approach it has adopted is consistent with the goals of the Directive and provides a credible pathway for meeting its targets.

RED III defines renewable energy in the transport sector as encompassing renewable electricity supplied to battery-powered vehicles, renewable hydrogen supplied to fuel cell vehicles, biogases supplied to gas combustion vehicles, renewable liquid and gaseous fuels of non-biological origin, and liquid biofuels. Each of these must satisfy certain criteria to comply with the Directive. Biofuels are subject to a set of basic sustainability criteria, which include (i) a prohibition on sourcing feedstock from lands that have since 2008 been converted from forests, peatlands, and wetlands (unless it can be shown that doing so would not disturb natural services), and (ii) a minimum reportable reduction in 'lifecycle' greenhouse gas emissions compared to a fossil fuel comparator of 94 gCO_2e/MJ (grams of carbon dioxide equivalent per megajoule of fuel energy). These criteria will be examined more closely in the following sections.

Appendix A.3. Conflation of Terms

As a general note on high and low ILUC-risk, it is worth mentioning that the general literature on this topic is known to conflate the term 'high-ILUC' with 'high ILUC-risk', and 'low-ILUC' with 'low ILUC-risk'. High/low-ILUC (without the '-risk') has no technical policy meaning (at least in the EU); but it colloquially suggests that the crop class under examination has been associated with high/low-ILUC emissions informed by the results of economic modelling studies. The terms high/low ILUC-risk have, as we have seen in the previous sections, technical meanings. The high ILUC-risk tag can be applied to entire crop types (at present only oil palm is affected); the low ILUC-risk tag applies only to certain batches of feedstock from certified farms (or certain batches of biofuel from certified production plants) that have satisfied the additionality criteria.

To make this more concrete, a crop like soybean may be considered high-ILUC without necessarily meeting the conditions to be categorised as high ILUC-risk. Similarly, a crop like the oilseed camelina [81] may be considered to be generically low-ILUC, independently of whether it has undergone the stringent certification requirements to be labelled as low ILUC-risk. In short, a given batch of feedstock or biofuel designated high/low ILUC-risk is likely to be high/low-ILUC, but not the other way around.

Appendix B. Considerations for Creating a Workable Low ILUC-Risk System

Appendix B.1. Scaling Low ILUC-Risk Projects in the EU

This paper has primarily focussed on the rarefied level of policy. Pressing beyond this, it behoves us to also consider the potential for developing on-ground projects compatible with the low ILUC-risk concept. At the time of writing, two EU consortia have published case studies on the deployment of low ILUC-risk production models and the practicalities of certification [26,38]. A key question surrounding these projects concerns the scalability of the case studies: the extent to which they may be replicated and hence the amount of

low ILUC-risk feedstock that could conceivably be produced. In order to assess whether and where a given low ILUC-risk production model has potential to deliver, we need to consider three key dimensions: feedstock supply potential, industrial capacity for offtake of the same, and whether there exists and enabling policy environment.

For the EU-27 + UK, the first two of these dimensions have been addressed directly in reports from the BIKE project. The potential for supplying biofuel feedstock from yield improvements on existing agricultural land was considered at the sub-national level in [56], and the potential for converting unused and abandoned land to various forms of bioenergy production was assessed in [61]. Meanwhile, the existing capacity for fuel conversion, and the potential siting of future capacity, was mapped in [82,83], respectively. A synthesis of these culminated in the creation of a 'transferability matrix' identifying the countries that are best suited for the production and use of low ILUC-risk feedstocks [27]. Sweden, Spain, the Netherlands, Austria, Hungary, Italy, and Slovakia were all classed in the top category (of three), as they scored highly in multiple categories.

This being said, any large-scale development of low ILUC-risk production in these areas would be contingent on the existence of enabling policies helping putative projects to overcome the identified barriers. Some of these barriers affect the existing low ILUC-risk system as a whole, while others are unique to a particular low ILUC-risk production model in a particular area [27].

What the literature needs now are some well-worked case studies that go into more depth about project business models, costs, revenues, and subsidies. This would be necessary to identify what kinds of agricultural projects could plausibly become viable under different near-term policy scenarios. Initial work along these lines has indeed found that the extra costs of biomass production on lower-quality agricultural land, say, could be offset by revenues from the sale of additional biofuel feedstock [60]. However, the precise value boost from low ILUC-risk certification was not considered in this work. This leaves room for a cost–benefit analysis of specific low ILUC-risk production models.

Appendix B.2. Effective Sustainability Standards

If low ILUC-risk is to be positioned as a credible sustainability standard, then it is vital that the certification requirements are stringent enough to give assurance that genuine climate benefits are being delivered without excessive trade-offs in other areas. This is a sensitive issue because the low ILUC-risk system was designed to deliver 'food and feed' crops into the biofuel sector; a hypothetical poorly conceived certification system that is vulnerable to abuse could end up scoring an own goal: by diverting crops away from legitimate food and feed markets and into the bioenergy space, under the guise of a gold-plated sustainability standard. This would have exactly the opposite effect of what is intended: creating additional demand for 'food and feed' crops, raising prices, and stimulating agricultural expansion elsewhere; see, e.g., the conclusion of [19]. In short, we seek to design a water-tight standard that can all but guarantee that certified material is genuinely additional.

At the same time, this pursuit of stringency implies a rigorous and technical assessment regime—one that may be costly for farmers and farmer groups in terms of labour, time, and funds. As certification schemes develop (e.g., to assess whether batches of crop-based biofuels meet the general RED requirements), norms may emerge to share costs between feedstock producers and fuel producers through long-term offtake agreements. There may also be a role for interested governments to subsidise or facilitate the certification process.

Regardless of how streamlined the process becomes, it is natural to expect that the farmers (et al.) would only deem certification to be worthwhile if they were motivated by a strong and/or reliable value signal. This is a major issue for the low ILUC-risk system, as at present, there is no clear basis for low ILUC-risk certification to bring in additional revenue (except for palm oil farmers). One could argue that certification could confer some sort of 'reputational advantage' as an extra layer of sustainability assurance, but these are difficult to quantify. Given that the low ILUC-risk concept is complex, at present lacks

brand recognition, and has only recently become part of certification bodies' repertoire, it is unsurprising that there is no established market that commodifies and quantifies the value that this reputational advantage might have to a biofuel producer.

Appendix C. Thematic Headings

During the policy review phase, the relevance of EU policy provisions to the low ILUC-risk system were classified under the thematic headings in Table A1. This allowed for the identification of common aims and methods among disparate policy texts and frameworks. Each provision was further categorised according to Table 1 in the main body of the paper.

Table A1. Classification of EU policy provisions in terms of their impact on the low ILUC-risk system.

#	Heading	Elaboration
1	Exemption from the High-ILUC cap	Policies that exempt certified low-ILUC material from the diminishing RED II cap on high-ILUC feedstocks.
2	Exemption from Food Crop Caps	Policies that permit low-ILUC feedstocks to count differently towards national food and feed caps.
3	Contribution to Renewable Energy Targets	Policies that would give low-ILUC biofuels preferential treatment in contributing to renewable energy targets, as compared with other biofuels.
4	ILUC Emissions Factor	Policies that incentivise reductions in emissions, and that would therefore give preference to those biofuel projects where the ILUC factor can be set to zero.
5	Land Conversion Emissions	Policies that ascribe emissions to direct land use change will impact agricultural projects that seek to convert unused land.
6	Unused and Marginal Land	Policies that incentivise or regulate the conversion of unproductive land into productive agricultural land.
7	Habitats and Pollution	Policies that seek to enhance biodiversity through the provision of habitats, and the mitigation of local pollution.
8	Soil Carbon Management	Policies that explicitly encourage soil carbon sequestration, either through promoting certain management practices or by considering the results of direct measurement/modelling.
9	Soil Health and Water Conservation	Policies that support measures to preserve soil structure/biome/drainage and the conservation of water resources.
10	Rural Social Measures	Policies that seek to encourage smallholder projects or traditional production methods, which may be suitable for integration with a low-ILUC system.
11	Contribution to Agricultural Sustainability Goals	Policies establishing sustainability standards (for projects, processes, or products), which could be satisfied by low-ILUC material.
12	Energy Feedstock Reporting	Policies that specifically promote the production and consumption of sustainable biofuels by imposing feedstock-related requirements (or reporting obligations).
13	Reporting Standardisation	Policies that impose reporting requirements on biogenic material may overlap with the low-ILUC certification system, opening the door to harmonisation of standards.
14	Project Finance	Policies that make projects eligible for funding (or financial support) based on sustainability criteria that could reasonably be satisfied by low-ILUC certification.
15	Information Access	Policies that increase the availability of useful information, or the accessibility of tools that can assist in meeting low-ILUC certification requirements.
16	Other Narrative Relevance	Policies which increase the availability of useful information, or the accessibility of tools that can assist in meeting low-ILUC certification requirements.

Appendix D. Policy Texts Reviewed

Table A2 lists selected policy texts considered in the present analysis, in no particular order. References are given to one or more key documents or websites.

Table A2. Non-exhaustive list of EU-level texts reviewed in the policy landscape mapping phase of the research.

Policy	Reference
RED II	[6]
RED III	[4]
ILUC Directive	[24]
ILUC-risk Delegated Regulation	[34]
Implementing Regulation on Voluntary Schemes	[16]
FSDN Communication	[84]
Sustainable Finance Taxonomy Regulation	[85–87]
Carbon Removal Regulation (proposal)	[88]
Sustainable Carbon Cycles Communication	[89]
CAP 2021	[90]
CAP 2013	[91–93]
LULUCF Regulation	[94]
Natura 2000	[95]
Forest Strategy	[96–99]
Fuels Quality Directive	[100]
REDD+	[101,102]
EU Rural Vision	[103]
EIP Agri/EU CAP Network	[104,105]
Habitats Directive	[106]
Birds Directive	[107]
Soil Strategy for 2030	[44]
Nitrates Directive	[108]
EU Taxonomy	[85,86]
Cohesion Fund and Regional Development Fund Regulation	[109]
Renewable Energy Financing Mechanism	[110]
Recovery and Resilience Facility	[111]
InvestEU	[112]
Connecting Europe Facility (Energy)	[113]
EAFRD & EAGF	[114]
Just Transition Mechanism	[115]
Innovation Fund	[116]
Modernisation Fund	[117]
Horizon Europe	[118]
Farm to Fork Strategy	[119]
Biodiversity Strategy	[120]
Invasive Alien Species Regulation	[121]
Sustainable Use of Pesticides	[122]
Fertilising Products Regulation	[123]
Clean Air Programme	[124]
Water Framework Directive	[125]
Circular Economy Package	[126]
Energy Efficiency Directive	[127]
Emission Trading System	[128]
ReFuelEU Aviation	[129,130]
FuelEU Maritime	[131,132]

References

1. European Court of Auditors. The EU's Support for Sustainable Biofuels in Transport: An Unclear Route ahead. 2023. Available online: https://www.eca.europa.eu/ECAPublications/SR-2023-29/SR-2023-29_EN.pdf (accessed on 31 March 2024).
2. Valin, H.; Peters, D.; van den Berg, M.; Frank, S.; Havlik, P.; Forsell, N.; Hamelinck, C. The Land Use Change Impact of Biofuels in the EU: Quantification of Area and Greenhouse Gas Impacts. 2015. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/FinalReport_GLOBIOM_publication.pdf (accessed on 31 March 2024).

3. Laborde, D. *Assessing the Land Use Change Consequences of European Biofuel Policies*; Specific Contract No SI2. 580403; European Commission: Washington, DC, USA, 2011.
4. European Union. Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 Amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as Regards the Promotion of Energy from Renewable Sources, and Repealing Council. *Off. J. Eur. Union* **2023**, *2413*, 1–77.
5. European Commission. Renewable Energy Directive. 2023. Available online: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en (accessed on 5 March 2024).
6. European Union. Directive (EU) 2018/2001 of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources. *Off. J. Eur. Union* **2018**, *L328*, 82–209.
7. Zygierewicz, A.; Sanz, L.S. European Parliament Briefing | Revision of Directive (EU) 2018/2001. 2021. Available online: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/662619/EPRS_BRI(2021)662619_EN.pdf (accessed on 31 March 2024).
8. Soquet-Boissy, A.; Koster, M.; De Simone, F.; Vion, M.; Saint-Supéry. Overview of Biofuels Policies and Markets across the EU. 2024. Available online: https://www.epure.org/wp-content/uploads/2023/02/230227-DEF-REP-Overview-of-biofuels-policies-and-markets-across-the-EU-February-2023-1.pdf (accessed on 31 March 2024).
9. Peters, D.; Zabeti, M.; Kühner, A.-K.; Spöttle, M.; van der Werf, W.; Stomph, T.J. Assessing the Case for Sequential Cropping to Produce Low ILUC-risk Biomethane. 2016. Available online: https://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2017/02/2016_Ecofys_Assessing-benefits-sequential-cropping.pdf (accessed on 31 March 2024).
10. Brinkman, M.L.J.; van der Hilst, F.; Faaij, A.P.C.; Wicke, B. Low ILUC-risk rapeseed biodiesel: Potential and indirect GHG emission effects in Eastern Romania. *Biofuels* **2021**, *12*, 171–186. [CrossRef]
11. Brinkman, M.L.J.; Wicke, B.; Faaij, A.P.C. Low ILUC-risk ethanol from Hungarian maize. *Biomass Bioenergy* **2017**, *99*, 57–68. [CrossRef]
12. Abreu, M.; Silva, L.; Ribeiro, B.; Ferreira, A.; Alves, L.; Paixão, S.M.; Gouveia, L.; Moura, P.; Carvalheiro, F.; Duarte, L.C.; et al. Low Indirect Land Use Change (ILUC) Energy Crops to Bioenergy and Biofuels—A Review. *Energies* **2022**, *15*, 4348. [CrossRef]
13. Alexopoulou, E. BIKE Deliverable D6.1 | Reports for the Good Practice Cases. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/03/20230228_BIKE_D6.1_1.0_CRES.pdf (accessed on 31 March 2024).
14. Strapasson, A.; Falcão, J.; Rossberg, T.; Buss, G.; Woods, J.; Peterson, S. Land Use Change and the European Biofuels Policy: The expansion of oilseed feedstocks on lands with high carbon stocks. *OCL—Oilseeds Fats Crops Lipids* **2019**, *26*, 39. [CrossRef]
15. Hinkes, C. Adding (bio)fuel to the fire: Discourses on palm oil sustainability in the context of European policy development. *Environ. Dev. Sustain.* **2020**, *22*, 7661–7682. [CrossRef]
16. European Commission. Commission Implementing Regulation (EU) 2022/996. *Off. J. Eur. Union* **2022**, *L168*, 1–62. Available online: https://eur-lex.europa.eu/eli/reg_impl/2022/996/oj (accessed on 14 February 2023).
17. Dusser, P. The European Energy Policy for 2020–2030 RED II: What future for vegetable oil as a source of bioenergy? *OCL* **2019**, *26*, 51. [CrossRef]
18. Sumfleth, B.; Majer, S.; Thrän, D. Recent developments in low ILUC policies and certification in the EU biobased economy. *Sustainability* **2020**, *12*, 8147. [CrossRef]
19. Sandford, C.; Malins, C.; Panoutsou, C. Challenges and Recommendations for Improved Identification of Low ILUC-Risk Agricultural Biomass. *Appl. Sci.* **2023**, *13*, 6349. [CrossRef]
20. Malins, C. Risk Management: Identifying High and Low ILUC-Risk Biofuels under the Recast Renewable Energy Directive. 2019. Available online: http://www.cerulogy.com/wp-content/uploads/2019/01/Cerulogy_Risk-Management_Jan2019.pdf (accessed on 15 February 2023).
21. Malins, C. Considerations for Addressing Indirect Land Use Change in Danish Biofuel Regulation. 2021. Available online: https://ens.dk/sites/ens.dk/files/Basisfremskrivning/chris_malins_rapport_-_conciderations_for_adressing_iluc_in_danish_biofuel_regulation.pdf (accessed on 31 March 2024).
22. Eurostat. Use of Renewables for Transport | nrg_ind_urtd. 2024. Available online: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_urtd/default/table?lang=en&category=nrg.nrg_quant.nrg_quanta.nrg_ind_share (accessed on 15 March 2024).
23. European Commission. Directive 2009/28/EC of the European Parliament and of the Council—Consolidated. 2015. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02009L0028-20151005 (accessed on 31 March 2024).
24. European Union. Directive (EU) 2015/1513 of the European Parliament and of the Council. *Off. J. Eur. Union* **2015**, *2014*, 20–30.
25. Sandford, C.; Malins, C.; Vourliotakis, G.; Politi, M.; Mutua, K.; Kulmany, I.; Panoutsou, C. BIKE Deliverable D5.1 | Assessment of the Frameworks and Recommendations about Enabling Policies. 2022. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2022/10/BIKE_WP5_D5.1_1.0.pdf (accessed on 31 March 2024).
26. BIKE. BIKE | Safe and Reliable Biomass Value Chains for Sustainable Biofuels and the Bioeconomy. 2023. Available online: https://www.bike-biofuels.eu/ (accessed on 4 March 2024).
27. Sandford, C.; Malins, C.; Panoutsou, C.; Dauda, I.; Giarola, S.; Sevigne Etoiz, E.; Shah, N.; Vourliotakis, G.; Athanasopoulou, M. BIKE Deliverable D5.2 | Low ILUC-Risk Policy Framework for the BIKE Case Studies. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2024/02/D5.2.pdf (accessed on 31 March 2024).
28. Government of Germany. Federal Immission Control Act—BImSchG. In *Fassung des Bundesgesetzblatts*; 2023. Available online: https://www.gesetze-im-internet.de/bimschg/ (accessed on 31 March 2024).

29. Government of Belgium. Law Amending the Act of 17 July 2013 on the Minimum Nominal Volumes of Sustainable Biofuels That Must Be Incorporated into the Volumes of Fossil Fuels Released for Consumption Annually. Monit. Belge/Belgisch Staatsbl. 2022. Available online: https://refli.be/fr/lex/2022043065 (accessed on 31 March 2024).
30. Malins, C. Soy, Land Use Change and ILUC-Risk: A Review. 2020. Available online: https://www.transportenvironment.org/wp-content/uploads/2021/07/2020_11_Study_Cerulogy_soy_and_deforestation.pdf (accessed on 31 March 2024).
31. Häusling, M.; Wölken, T.; Rego, S. Parliamentary Question P-002310/2023 | Reducing the High ILUC-risk Threshold to Progressively Halt Deforestation, Starting with Soy, and Accelerating the Phase-Out Trajectory. 2023. Available online: https://www.europarl.europa.eu/doceo/document/P-9-2023-002310_EN.html (accessed on 31 March 2024).
32. Transport & Environment. Civil Society Groups Call for End to Soy Biofuels. 2024. Available online: https://www.transportenvironment.org/discover/civil-society-groups-call-on-eu-commission-to-end-support-for-damaging-soy-biofuels/ (accessed on 5 March 2024).
33. Heilmayr, R.; Heilmayr, R.; Carlson, K.M.; Carlson, K.M.; Benedict, J.J. Deforestation spillovers from oil palm sustainability certification. *Environ. Res. Lett.* **2020**, *15*, 075002. [CrossRef]
34. European Commission. Comission Delegated Regulation (EU) 2019/807. *Off. J. Eur. Union* **2019**, *L133*, L133/1.
35. Sumfleth, B.; Majer, S.; Thrän, D. A Review of Trade-Offs in Low ILUC-Risk Certification for Biofuels—Towards an Integrated Assessment Framework. *Sustainability* **2023**, *15*, 16303. [CrossRef]
36. ISCC. ISCC PLUS Add-on 202-07: Low ILUC-Risk Feedstock Certification. 2023. Available online: https://www.iscc-system.org/wp-content/uploads/2023/11/ISCC_PLUS_lowILUC_V1.0_July2023_Final.pdf (accessed on 31 March 2024).
37. Roundtable for Sustainable Biomaterials. RSB Standard for EU Market Access. 2024. Available online: https://rsb.org/wp-content/uploads/2020/06/RSB-STD-11-001-v.5.1-Standard-for-EU-market-access.pdf (accessed on 31 March 2024).
38. Guidehouse; IIASA; GRAS; IEEP; Cerulogy; ISCC; Control Union; E4tech. High and Low ILUC-Risk Fuels | Technical Assistance for the European Commission. 2023. Available online: https://iluc.guidehouse.com/ (accessed on 4 March 2024).
39. European Commission. SWD/2021/0115 Final. Commission Staff Working Document Evaluation of the Impact of the Common Agricultural Policy on Climate Change and Greenhouse Gas Emissions. 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021SC0115 (accessed on 31 March 2024).
40. Erekalo, K.T.; Pedersen, S.M.; Christensen, T.; Denver, S.; Gemtou, M.; Fountas, S.; Isakhanyan, G. Review on the contribution of farming practices and technologies towards climate-smart agricultural outcomes in a European context. *Smart Agric. Technol.* **2024**, *7*, 100413. [CrossRef]
41. Montanarella, L.; Panagos, P. The relevance of sustainable soil management within the European Green Deal. *Land Use Policy* **2021**, *100*, 104950. [CrossRef]
42. Paul, C.; Bartkowski, B.; Dönmez, C.; Don, A.; Mayer, S.; Steffens, M.; Weigl, S.; Wiesmeier, M.; Wolf, A.; Helming, K. Carbon farming: Are soil carbon certificates a suitable tool for climate change mitigation? *J. Environ. Manag.* **2023**, *330*, 117142. [CrossRef]
43. European Commission. *Proposal for a Directive of the European Parliament and of the Council on Soil Monitoring and Resilience (Soil Monitoring Law) COM(2023) 416 Final*; European Commission: Luxembourg, 2023. [CrossRef]
44. European Commission. EU Soil Strategy for 2030. Reaping the benefits of healthy soils for people, food, nature and climate. COM(2021) 699 final. In *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*; European Commission: Luxembourg, 2021; pp. 1–26. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0699 (accessed on 31 March 2024).
45. BIKE. BIKE Briefing Note #11 | Sustainability Indicators for Food and Biofuel Production. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/07/BIKE_WP5_BriefingNote_11-Sustainability-Indicators.pdf (accessed on 31 March 2024).
46. Malins, C. Understanding the Indirect Land Use Change Analysis for CORSIA. 2019. Available online: https://www.transportenvironment.org/wp-content/uploads/2021/07/2019_12_Cerulogy_ILUC-in-CORSIA.pdf (accessed on 31 March 2024).
47. Pavlenko, N.; Searle, S. A Comparison of Induced Land-Use Change Emissions Estimates from Energy Crops. 2018. Available online: https://theicct.org/wp-content/uploads/2021/06/ILUC-energy-crops_ICCT-White-Paper_06022018_vF1.pdf (accessed on 31 March 2024).
48. European Commission. Commission Delegated Directive amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council, as Regards Adding Feedstocks for the Production of Biofuels and Biogas. 2022. Available online: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13484-Biofuels-updated-list-of-sustainable-biofuel-feedstocks_en (accessed on 31 March 2024).
49. European Commission. Annex to the Commission Delegated Directive (EU) amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council, as Regards Adding Feedstock for the Production of Biofuels and Biogas. 2024. Available online: https://ec.europa.eu/info/law/better-regulation/ (accessed on 31 March 2024).
50. BIKE. BIKE Briefing Note #6 | Low ILUC-Risk Crops and Annex IX. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/06/BIKE_WP5_BriefingNote_6-Low-ILUC-risk-crops-and-Annex-IX.pdf (accessed on 31 March 2024).
51. European Commission. Commission Delegated Directive Amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council, as Regards Adding Feedstocks for the Production of Biofuels and Biogas | Consultation Responses. 2022. Available online: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13484-Biofuels-updated-list-of-sustainable-biofuel-feedstocks/feedback_en?p_id=31725204 (accessed on 14 March 2024).

52. Christensen, A. Intermediate Crops in the Renewable Energy Directive. 2021. Available online: https://theicct.org/sites/default/files/publications/intermediate-crops-RED-II-eu-oct21.pdf (accessed on 31 March 2024).
53. van Dam, J.; Ugarte, S. Accessibility and Traceability in Sustainable Biofuel Supply-Chains. 2020. Available online: https://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2020/06/2020_SQ-Consult_Accessibility-and-traceability-in-sustainable-biofuel-supply_Final-report_pdf.pdf (accessed on 31 March 2024).
54. Koster, M.; De Simone, F.; Saint-Supéry, M.V. Overview of Biofuels Policies and Markets across the EU. 2022. Available online: https://www.epure.org/wp-content/uploads/2022/10/221011-DEF-REP-Overview-of-biofuels-policies-and-markets-across-the-EU-October-2022.pdf (accessed on 31 March 2024).
55. European Commission. March Infringements Package: Key Decisions. 2024. Available online: https://ec.europa.eu/commission/presscorner/detail/EN/inf_24_663 (accessed on 15 March 2024).
56. Panoutsou, C.; Sandford, C.; Malins, C.; Mutua, K.; Takacs, E.; Szlatenyi, D.; Boogaard, H.; Staritsky, I.; de Wit, A.; Verzandvoort, S.; et al. BIKE Deliverable D2.1 | Productivity Increases That Can Result in Additional Feedstock for European Biomass Crop Options. 2022. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2022/10/D2_1-Productivity-increase-final.pdf (accessed on 31 March 2024).
57. FAO. Dataset | Crops and Livestock Products. 2024. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 15 March 2024).
58. BIKE. BIKE Briefing Note #9 | CAP Support for Sustainable Low ILUC-Risk Feedstock Production. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/07/BIKE_WP5_BriefingNote_9-CAP-Subsidies.pdf (accessed on 31 March 2024).
59. BIKE. BIKE Briefing Note #10 | Ecologically Appropriate Crops for Restoration of Unused and Severely Degraded Lands. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/07/BIKE_WP5_BriefingNote_10-Inputs-Unused-Land.pdf (accessed on 31 March 2024).
60. Panoutsou, C.; Giarola, S.; Ibrahim, D.; Verzandvoort, S.; Elbersen, B.; Sandford, C.; Malins, C.; Politi, M.; Vourliotakis, G.; Zita, V.E.; et al. Opportunities for Low Indirect Land Use Biomass for Biofuels in Europe. *Appl. Sci.* **2022**, *12*, 4623. [CrossRef]
61. Elbersen, B.; Verzandvoort, S.; Alexopoulou, E.; Panoutsou, C. BIKE Deliverable D2.2 | Options to Grow Crops on Unused, Abandoned and/or Severely Degraded Lands. 2022. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2022/10/Deliverable-2.2-Final.pdf (accessed on 31 March 2024).
62. Fayet, C.M.J.; Reilly, K.H.; Van Ham, C.; Verburg, P.H. What is the future of abandoned agricultural lands? A systematic review of alternative trajectories in Europe. *Land Use Policy* **2022**, *112*, 105833. [CrossRef]
63. Fayet, C.M.J.; Reilly, K.H.; Van Ham, C.; Verburg, P.H. The potential of European abandoned agricultural lands to contribute to the Green Deal objectives: Policy perspectives. *Environ. Sci. Policy* **2022**, *133*, 44–53. [CrossRef]
64. FAO. FORBIO Deliverable D3.3—Final Report on the Sustainability Assessment of the Selected Advanced Bioenergy Value Chains in All the Case Study Sites. 2018. Available online: https://www.researchgate.net/publication/350048391_Final_report_on_the_sustainability_assessment_of_the_selected_advanced_bioenergy_value_chains_in_all_the_case_study_sites (accessed on 31 March 2024).
65. Valujeva, K.; Debernardini, M.; Freed, E.K.; Nipers, A.; Schulte, R.P.O. Abandoned farmland: Past failures or future opportunities for Europe's Green Deal? A Baltic case-study. *Environ. Sci. Policy* **2022**, *128*, 175–184. [CrossRef]
66. Crawford, C.L.; Yin, H.; Radeloff, V.C.; Wilcove, D.S. Rural land abandonment is too ephemeral to provide major benefits for biodiversity and climate. *Sci. Adv.* **2022**, *8*, eabm8999. [CrossRef]
67. Isbell, F.; Tilman, D.; Reich, P.B.; Clark, A.T. Deficits of biodiversity and productivity linger a century after agricultural abandonment. *Nat. Ecol. Evol.* **2019**, *3*, 1533–1538. [CrossRef] [PubMed]
68. Jámbor, A.; Török, Á. The economics of Arundo donax: A systematic literature review. *Sustainability* **2019**, *11*, 4225. [CrossRef]
69. Pilu, R.; Bucci, A.; Badone, F.C.; Landoni, M. Giant reed (*Arundo donax* L.): A weed plant or a promising energy crop? *Afr. J. Biotechnol.* **2012**, *11*, 9163–9174. [CrossRef]
70. Kehoe, L.; Romero-Muñoz, A.; Polaina, E.; Estes, L.; Kreft, H.; Kuemmerle, T. Biodiversity at risk under future cropland expansion and intensification. *Nat. Ecol. Evol.* **2017**, *1*, 1129–1135. [CrossRef]
71. Zabel, F.; Delzeit, R.; Schneider, J.M.; Seppelt, R.; Mauser, W.; Václavík, T. Global impacts of future cropland expansion and intensification on agricultural markets and biodiversity. *Nat. Commun.* **2019**, *10*, 2844. [CrossRef] [PubMed]
72. Mai-Moulin, T.; Hoefnagels, R.; Grundmann, P.; Junginger, M. Effective sustainability criteria for bioenergy: Towards the implementation of the european renewable directive II. *Renew. Sustain. Energy Rev.* **2021**, *138*, 110645. [CrossRef]
73. BIKE. BIKE Briefing Note #7 | Soil Carbon Crediting and the Low ILUC-Risk System. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/05/BIKE_WP5_BriefingNote_7-Soil-Carbon-Credit.pdf (accessed on 31 March 2024).
74. BIKE. BIKE Briefing Note #8 | Sustainably Delivering Carbon Farming and Low ILUC-Risk. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/04/BIKE_WP5_BriefingNote_8-Carbon-Farming-Sustainability.pdf (accessed on 31 March 2024).
75. BIKE. BIKE Briefing Note #13 | Soil Sampling and Soil Organic Carbon across Agricultural Landscapes. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/07/BIKE_WP5_BriefingNote_13-SOC-Estimation-1.pdf (accessed on 31 March 2024).

76. Giuntoli, J. Final Recast Renewable Energy Directive for 2021–2030 in the European Union. 2018. Available online: https://theicct.org/publication/final-recast-renewable-energy-directive-for-2021-2030-in-the-european-union/ (accessed on 31 March 2024).
77. Baldino, C. Provisions for Transport Fuels in the European Union's Finalized 'Fit for 55' Package. 2023. Available online: https://theicct.org/wp-content/uploads/2023/07/fuels-fit-for-55-red-iii-jul23.pdf (accessed on 31 March 2024).
78. Norwegian Ministry of Finance. Tax Rates 2023. 2023. Available online: https://www.regjeringen.no/no/tema/okonomi-og-budsjett/skatter-og-avgifter/avgiftssatser-2023/id2929584/ (accessed on 5 September 2023).
79. Government of the Netherlands. Energy Transport Decree. 2022. Available online: https://wetten.overheid.nl/BWBR0040922/2022-01-01 (accessed on 31 March 2024).
80. Government of Sweden.Act (2017:1201) on the Reduction of Greenhouse Gas Emissions from Certain Fossil Fuels. 2022. Available online: https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/lag-20171201-om-reduktion-av-vaxthusgasutslapp_sfs-2017-1201/ (accessed on 31 March 2024).
81. Zanetti, F.; Alberghini, B.; Marjanović Jeromela, A.; Grahovac, N.; Rajković, D.; Kiprovski, B.; Monti, A. Camelina, an ancient oilseed crop actively contributing to the rural renaissance in Europe. A review. *Agron. Sustain. Dev.* **2021**, *41*, 2. [CrossRef]
82. Salimbeni, A. BIKE Deliverable D3.1 | Overview on Biofuels Production Facilities and Technologies in Europe. 2021. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2021/09/20210914_BIKE_D3.1_4.0_REC.pdf (accessed on 31 March 2024).
83. Borchi, C.; Salimbeni, A. BIKE Deliverable D3.3 | Replication Potential of Case Studies Examined in BIKE. 2023. Available online: https://www.bike-biofuels.eu/wp-content/uploads/2023/07/Deliverable-D3.3_BIKE-2.pdf (accessed on 31 March 2024).
84. European Commission. Proposal for a Regulation of the European Parliament and of the Council Amending Council Regulation (EC) No 1217/2009 as Regards Conversion of the Farm Accountancy Data Network into a Farm Sustainability Data Network | COM/2022/296 Final. 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2022:296:FIN (accessed on 31 March 2024).
85. European Union. Taxonomy Regulation | Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020. *Off. J. Eur. Union* **2020**, *L 198*, 13–43.
86. European Commission. Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021. *Off. J. Eur. Union* **2021**, *442*, 1–349.
87. European Commission. Taxonomy Report: Technical Annex. Updated Methodology & Updated Technical Screening Criteria. 2020. Available online: https://finance.ec.europa.eu/system/files/2020-03/200309-sustainable-finance-teg-final-report-taxonomy-annexes_en.pdf (accessed on 31 March 2024).
88. European Commision. Proposal for a Regulation Establishing a Union Certification Framework for Carbon Removals | COM(2022) 672 Final. 2022. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0672 (accessed on 31 March 2024).
89. European Commission. *Sustainable Carbon Cycles | COM(2021) 800 Final*; European Commission: Brussels, Belgium, 2021. [CrossRef]
90. European Union. CAP Strategic Plan 2021 | Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021. *Off. J. Eur. Union* **2021**, *2021*, 435/1–435/186. Available online: https://eur-lex.europa.eu/eli/reg/2021/2115/oj (accessed on 31 March 2024).
91. European Union. Regulation (EU) 1305/2013 of the European Parliament and of the Council of 17 December 2013 on Support for Rural Development by the European Agricultural Fund for Rural Development (EAFRD) and Repealing Council Regulation (EC) No 1698/2005. 2013. Available online: https://eur-lex.europa.eu/eli/reg/2013/1305/oj (accessed on 31 March 2024).
92. European Union. Regulation (EU) 1306/2013 of the European Parliament and of the Council on the Financing, Management and Monitoring of the Common Agricultural Policy. *Off. J. Eur. Union* **2013**, *L347/549*, 549–607. Available online: https://eur-lex.europa.eu/eli/reg/2013/1306/oj (accessed on 31 March 2024).
93. European Union. Regulation (EU) No 1307/2013 of the European Parliament and of the Council Establishing Rules for Direct Payments to Farmers under Support Schemes within the Framework of the Common Agricultural Policy and Repealing Council Regulati. *Off. J. Eur. Union* **2013**, *2008*, 608–670. Available online: https://eur-lex.europa.eu/eli/reg/2013/1307/oj (accessed on 31 March 2024).
94. European Union. Regulation (EU) 2018/841. 2018. Available online: https://eur-lex.europa.eu/eli/reg/2018/841/oj (accessed on 31 March 2024).
95. European Commission. Natura 2000. 2023. Available online: https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000_en (accessed on 19 April 2024).
96. European Commission. *Forest Strategy for 2030 | COM(2021) 572 Final*; European Commission: Brussels, Belgium, 2021. [CrossRef]
97. European Commission. *Roadmap of the Commission's Action to Implement the Pledge to Plant 3 Billion Additional Trees by 2030 in the EU*; European Commission: Luxembourg, 2021; pp. 2021–2022.
98. European Commission. The 3 Billion Tree Planting Pledge for 2030. In *New EU Forest Strategy 2030*; European Commission: Luxembourg, 2021; pp. 11–28.
99. European Commission. A new EU Forest Strategy: For forests and the forest-based sector. In *Communication from the Commission to the European Parliament and the Council, the Economic and Social Committee and the Committee of the Regions*; no. SWD(2013) 342 final; European Commission: Luxembourg, 2013; p. 17. Available online: https://www.eea.europa.eu/policy-documents/the-eu-forest-strategy-com (accessed on 31 March 2024).

100. European Union. Directive 2009/30/EC of the European Parliament and of the Council. 2016. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02009L0030-20160610 (accessed on 26 January 2022).
101. European Union. Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010. *Off. J. Eur. Union* **2010**, *L 295*, 23–34.
102. European Commission. Addressing the Challenges of Deforestation and Forest Degradation to Tackle Climate Change and Biodiversity Loss | COM/2008/0645 Final. 2008. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52008DC0645 (accessed on 31 March 2024).
103. European Union. Rural Vision. 2021. Available online: https://rural-vision.europa.eu/index_en (accessed on 31 March 2024).
104. European Commission. EIP Agri. 2012. Available online: https://ec.europa.eu/eip/agriculture/en/ (accessed on 31 March 2024).
105. European Commission. EU CAP Network. 2023. Available online: https://eu-cap-network.ec.europa.eu/index_en (accessed on 31 March 2024).
106. European Commission. Consolidated Text: Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora. 2013. Available online: https://eur-lex.europa.eu/eli/dir/1992/43/2013-07-01 (accessed on 31 March 2024).
107. European Union. Directive 2009/147/EC of the European Parliement and of the Council of 30 November 2009 on the Conservation of Wild Birds (Codified Version). EUR-Lex. 2010. Available online: https://eur-lex.europa.eu/eli/dir/2009/147/oj (accessed on 31 March 2024).
108. European Council. Consolidated Text: Council Directive of 12 December 1991 Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources (91/676/EEC). 2008. Available online: https://eur-lex.europa.eu/eli/dir/1991/676/2008-12-11 (accessed on 31 March 2024).
109. European Union. Consolidated Text: Regulation (EU) 2021/1058 of the European Parliament and of the Council of 24 June 2021 on the European Regional Development Fund and on the Cohesion Fund. 2021. Available online: https://eur-lex.europa.eu/eli/reg/2021/1058 (accessed on 31 March 2024).
110. European Commission. EU Renewable Energy Financing Mechanism: Opening the Way for Private Investment. 2021. Available online: https://commission.europa.eu/news/eu-renewable-energy-financing-mechanism-opening-way-private-investment-2021-01-11_en (accessed on 22 April 2024).
111. European Commission. The Recovery and Resilience Facility. 2021. Available online: https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_en (accessed on 22 April 2024).
112. European Union. InvestEU. 2021. Available online: https://investeu.europa.eu/index_en (accessed on 31 March 2024).
113. European Commission. Connecting Europe Facility (Energy). 2018. Available online: https://wayback.archive-it.org/12090/20221207150821/https://ec.europa.eu/inea/connecting-europe-facility/cef-energy (accessed on 31 March 2024).
114. European Union. Regulation (EU) 2020/2220 of the European Parliament and of the Council of 23 December 2020 Laying Down Certain Transitional Provisions for Support from the European Agricultural Fund for Rural Development (EAFRD) and from the European Agricultural Guaran. 2020. Available online: https://eur-lex.europa.eu/eli/reg/2020/2220/oj (accessed on 31 March 2024).
115. European Commission. Proposal for a Regulation of the European Parliament and of the Council Establishing the Just Transition Fund | COM/2020/22 Final. 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020PC0022 (accessed on 31 March 2024).
116. European Commission. Innovation Fund Regulation. 2023. Available online: https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/legal-framework_en#innovation-fund-regulation (accessed on 31 March 2024).
117. European Commission. Modernisation Fund Commission Implementing Regulation (EU) 2020/1001. 2020. Available online: https://eur-lex.europa.eu/eli/reg_impl/2020/1001/oj (accessed on 31 March 2024).
118. European Commission. *Horizon Europe. Strategic Plan 2021–2024*; European Commission: Luxembourg, 2021. [CrossRef]
119. European Commission. A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System (COM 2020 381 Final). 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381 (accessed on 31 March 2024).
120. European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU Biodiversity Strategy for 2030 Bringing Nature Back into Our Lives | COM/2020/380 Final. EUR-Lex. 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380 (accessed on 31 March 2024).
121. European Union. Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species. 2014. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1143&from=EN (accessed on 31 March 2024).
122. European Union. Consolidated Text: Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 Establishing a Framework for Community Action to Achieve the Sustainable Use of Pesticides. EUR-Lex. 2019. Available online: https://eur-lex.europa.eu/eli/dir/2009/128/2009-11-25 (accessed on 31 March 2024).

123. European Union. Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 Laying Down Rules on the Making Available on the Market of EU Fertilising Products and Amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and Repealing Regula. 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1009&from=EN (accessed on 31 March 2024).
124. European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee And the Committee of the Regions a Clean Air Programme for Europe | COM/2013/0918 Final. EUR-Lex. 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52013DC0918 (accessed on 31 March 2024).
125. European Union. Water Framework Directive. 2000. Available online: https://environment.ec.europa.eu/topics/water/water-framework-directive_en (accessed on 31 March 2024).
126. European Commission. Circular Economy Action Plan. 2020. Available online: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (accessed on 31 March 2024).
127. European Union. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EU and Repealing Directives 2004/8/EC and 2006/32/EC. 2012. Available online: https://eur-lex.europa.eu/eli/dir/2012/27/oj (accessed on 31 March 2024).
128. European Union. Consolidated Text: Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 Establishing a System for Greenhouse Gas Emission Allowance Trading within the Union and Amending Council Directive 96/61/EC. 2023. Available online: https://eur-lex.europa.eu/eli/dir/2003/87/2023-01-21 (accessed on 31 March 2024).
129. European Commission. Proposal for a Directive of the European Parliament and of the Council Amending Directive 2003/87/EC as Regards Aviation's Contribution to the Union's Economy-Wide Emission Reduction Target and Appropriately Implementing a Global Market-Based Measure | CO. 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0552&qid=1643212295486 (accessed on 31 March 2024).
130. European Union. Consolidated Text: Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on Ensuring a Level Playing Field for Sustainable Air Transport (ReFuelEU Aviation). EUR-Lex. 2023. Available online: https://eur-lex.europa.eu/eli/reg/2023/2405 (accessed on 31 March 2024).
131. European Commission. Proposal for a Regulation of the European Parliament and of the Council on the Use of Renewable and Low-Carbon Fuels in Maritime Transport and Amending Directive 2009/16/EC | COM/2021/562 Final. EUR-Lex. 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0562 (accessed on 31 March 2024).
132. European Union. Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the Use of Renewable and Low-Carbon Fuels in Maritime Transport, and Amending Directive 2009/16/EC. 2023. Available online: https://eur-lex.europa.eu/eli/reg/2023/1805/oj (accessed on 31 March 2024).

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