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Article

Legal Harvesting, Sustainable Sourcing and Cascaded Use of Wood for Bioenergy: Their Coverage through Existing Certification Frameworks for Sustainable Forest Management

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Abstract: The first objective of this paper was to provide an inventory of developments of certification schemes for sustainable biomass production, following recent EU legislation (both formalized and under development). One main pillar is the EU Timber Regulation for legal harvesting; a second one is the EU's 2010 recommendations for sustainable woody biomass sourcing for energy; the third one is the EU Waste Directive. The second objective was to benchmark the coverage of this (draft) legislation, when wood product certificates for sustainable forest management (SFM) are used as proof of the related legislative requirements. We studied North America, as it is a major biomass supplier to the EU-28. Together with existing forest legislation in the US and Canada, SFM certificates are actively used to cover the EU's (draft) legislation. However, North American forests are only partially certified with fibers coming from certified forests; these are referred to as forest

management (FM) fibers. Other certified fibers should come from complementary risk assessments downstream in the supply chain (risk based fibers). Our benchmark concludes that: (a) FM fiber certification by the Forest Stewardship Council (FSC) and the Program for the Endorsement of Forest Certification (PEFC) international standards show the highest level of coverage with EU's (draft) legislation; (b) There is insufficient coverage for risk based fibers by FSC Controlled Wood (FSC-CW), PEFC Due Diligence (PEFC-DD), or SFI-fiber sourcing (SFI-FS). Other weaknesses identified for elaboration are: (c) Alignment in definitions are needed, such as for primary forest, high carbon stock, and wood waste (cascading); (d) Imperfect mass balance (fiber check downstream) needs to be solved, as non-certified fiber flows are inadequately monitored; (e) Add-on of a GHG calculation tool is needed, as GHG life cycle reporting is not covered by any of the SFM frameworks.

Keywords: sustainable forest management (SFM); certification; chain-of-custody (COC); solid biomass; bio-energy; North America; Europe; Renewable Energy Directive (RED); EU Timber Regulation (EUTR); Waste Directive

1. Introduction

The European Union (EU) promotes the use of renewable energy via the Renewable Energy Directive (RED) [1,2]. The EU-28 Member States have agreed on an average overall share of energy from renewable sources of 20% in gross final energy consumption in 2020. For comparison, the overall 2011 share of renewable sources was 10%, of which 4.8% was from the use of wood and wood-waste materials [3]. According to projections provided in the National Renewable Energy Action Plans, more than 10% of final energy consumption will be delivered by biomass by 2020 [4], with forest biomass playing a major role [5]. Legal sourcing of wood is relevant for forest biomass: new legislation, the EUTR, came into force in 2013. EUTR aims to prevent illegal logging of forests worldwide [6,7]. With an increasing market demand, additional issues, such as growing supply and securing sustainability of forest biomass for energy, need to be addressed [8]. With regards to the sustainable sourcing of solid biomass, the Commission has not yet proposed binding criteria at the EU level. The Commission implied, in its 2010 communications [9], that the wide variety of solid biomass feedstock make it difficult to put forward a harmonized scheme at this stage. Similar to the EU's framework for liquid biomass [1], solid biomass sourcing could be covered by national schemes and voluntary, EU approved schemes [10].

With rising demands for bioenergy from woody biomass, more intensive harvesting is practiced or under research in some areas, for example in Scandinavia, the United Kingdom, Canada and the United States [8,11–18]. Removal of additional forest biomass is expected to have greater impact on soil, water, and habitats than conventional forest practices in general. Usually, only the main part of the stem is removed, after which it is further processed by forest industries. Slash (branches and tops), small trees, and roots are commonly left in the forest as they are unsuitable for industrial processing [8]. On the one hand, with intensive biomass harvesting, sensitive forest soils can suffer from nutrient loss, which may result in lower forest re-growth than with conventional harvesting [11,15–19]. On the other hand, more intensive harvesting may be beneficial for natural regeneration under certain circumstances. According

to Swedish research [20], the survival rate of (pine) seedlings from natural regeneration is enhanced by slash and stump removal after the final harvest, due to improved soil conditions. Finally, natural disturbances provide the option of exceptional removal of dying or dead trees, called salvage logging [12]. For example, Canada continues to salvage timber from trees killed by the mountain pine beetle (MPB). In some areas, the affected trees are processed by sawmills; in others they are used as feedstock in pellets [21]. In an in-depth study [22], the impacts of salvage operation on soil fertility and biodiversity are stated to be a key knowledge gap.

Wood supply to the energy sector is sourced worldwide. To gain an impression of the volume of wood commodities for energy sourced by the EU, a brief overview of the main trading countries within and to the EU-28 is compiled in Table 1 (excluding domestic wood supplies). North America and Russia are among the main suppliers. The availability of pulpwood and fuelwood (low quality logs), industrial residues (chips, sawdust, shavings), processed residues (wood pellets) and post-consumer waste wood are relevant for bioenergy purposes. Industrial chips may include forest chips, but it is unknown to what extent. In 2012, about 4.3 million dry tonnes of industrial wood chips, 4.4 million tonnes of wood pellets, 1.8 million dry tonnes of sawdust and particles and 9.2 million dry tonnes of low quality logs were imported across EU borders [23]. Whereas pellets are 100% used by the energy sector [24], the other commodities can also be used by the forest sector industries for pulp and panels.

Sustainable wood sourcing becomes a critical factor in countries where forest legislation is not well enforced [25]. On top of forest legislation, certification of sustainable forest management (SFM) is relevant for the EU wood supplies [26]. The set-up of SFM frameworks involved significant challenges, such as the development of broadly supported criteria, harmonization with forest stewardship, and wood supply chain information [27–31]. It is, however, unclear whether, and to what extent, national legislation and voluntary certification are able to meet any additional sustainability criteria for solid biomass for energy.

As a first objective, this paper provides an inventory of developments of sustainable biomass production schemes, anticipating EU legislation (both formalized and under development). As a second objective, we set up a benchmark to gain more insight into the state-of-the-art of legal and sustainable sourcing, when wood product certificates for SFM are used as proof of the related legislative requirements. Our benchmark was triggered by the UK's legislation for solid biomass for renewable energy goals, which allows for legal and sustainable sourcing via existing frameworks for SFM certification [32–34]. The scope of this paper is to examine the full supply chain of woody biomass. We will start with boreal and temperate forests in North America, as the US and Canada are currently supplying the vast majority of solid biomass to the EU [23]. From the forests to plants in the EU's energy sector, we evaluated the suitability of major SFM schemes [35], anticipating the EUTR [6] for wood products, as well as the EU's official communications [9] for solid biomass [36] for energy. The potential woody feedstock for energy is considered to be [9,32]:

- Lower quality wood from forestry management, e.g., small trees, stumps, branches and other slash;
- Sawmill processing or other industrial wood residues, e.g., off-cuts, sawdust, and shavings, and
- Post-consumer waste wood (or recovered wood), e.g., construction and demolition waste wood.

Table 1. EU intra and EU extra imports of low quality logs and possible other energy wood commodities—2012 (in 1000 tonnes) [23].

	Wood pellets	**chips**		**Other residual wood**	**Low quality round wood ****	
Possible end uses		**Coniferous**	**Non Coniferous ***	(particles, sawdust and post-consumer wood waste)	Fuelwood	Pulpwood
- Wood based panels	0	large share (OSB, MDF)	large share (EU intra trade)	large share (particleboard)	0	large share
- Pulp and paper production	0	large share (pulp)	large share(EU extra trade)	low share	0	large share
- Larger scale power and heating (> 1 MW)	large share (EU extra trade)	growing share	negligible	growing feedstock for pellets	0	growing share for pellets
- Small scale heating (< 1 MW)	large share (EU intra trade)	substantial share	some share (birch)	negligible	residential heating	low share (birch, oak and beech)
- Other (e.g. stable litter, *etc.*)	negligible	0	0	negligible	0	0
EU total trade 2012	8,297	6,288	3,436	7,339	3,853	25,495
-EU extra trade 2012	**4,491**	**1,768**	**2,528**	**1,813**	**1,579**	**7,665**
-EU intra trade 2012	3,807	4,521	909	5,527	2,274	17,830
Top 10 of supplier countries for the individual type of biomass source and their market share						
	79%	78%	82%	54%	74%	73%
Supplier number 1	United States	Russia	Uruguay	Netherlands	UK	Latvia
Supplier number 2	Canada	Latvia	Chile	United Kingdom	Ukraine	Russia
Supplier number 3	Latvia	Germany	Russia	Norway	Bosnia Herzogovina	Germany
Supplier number 4	Russia	Rumania	Croatia	Switzerland	Croatia	Belarus
Supplier number 5	Germany	Estonia	Latvia	Bosnia Herzogovina	Hungary	Estonia
Supplier number 6	Estonia	Belarus	Belarus	Russia	Bulgaria	Spain
Supplier number 7	Portugal	Austria	Liberia	Belgium	Slovenia	Poland
Supplier number 8	Austria	Poland	Germany	Latvia	Germany	Norway
Supplier number 9	Ukraine	Finland	Estonia	Slovenia	Norway	France
Supplier number 10	Rumania	Belgium	Brazil	Austria	Latvia	Portugal

* NC chips are based on 2011, as 2012 figures are not yet fully registered; ** High quality poles and sawlogs are not applicable for energy use, and excluded from the trade figures.

Note that within certification frameworks, recycled fibers (post-consumer wood waste) have a special status, which is different from the status of forest biomass and of industrial wood residues.

Section 2 gives a brief overview of developments for sustainable biomass production in the EU. We continue with a methodological framework (Section 3) covering the EU legislation and the set-up of a benchmark. A suitability check for wood sourcing, related to EU legislation is given in Section 4 Benchmark results. Discussion and conclusions are given in Sections 5 and 6.

2. Overview of Developments Regarding Sustainable Woody Biomass Trade

The (worldwide) introduction of forest certification was started by the Forest Stewardship Council (FSC). FSC has one worldwide set of FM Principles and Criteria, often accompanied by country or region specific indicators. The FSC chain of custody (COC) standard is relevant to track the downstream supply of woody raw material and wood products to the end consumers [37]. Another large worldwide FM system is the Program for the Endorsement of Forest Certification schemes (PEFC). PEFC is an umbrella organization for the assessment and mutual recognition of national forest certification schemes. Corresponding to FSC, two types of certificates are available: PEFC-FM and PEFC-COC. PEFC-FM consists of sustainability criteria for forest maintenance and wood harvesting in the forest itself, whereas PEFC-COC is related to the downstream wood supply [38]. Note that the chain of custody for products with a FSC certificate is distinct from the ones with a PEFC certificate, as there is no full recognition between both types of certified fiber sources [39].

North America and Europe, including Russia, are currently the major suppliers of biomass for bioenergy to the EU-28, mainly through wood pellets and chips. A crosscut of North America and Europe shows, for both continents, an increasing forest area, combined with a considerable share of certified managed forests by FSC and PEFC (Table 2). The southeast region of the US, a major supplier of biomass to the EU, has few certified areas [40]. Due to overlapping certification, part of the certified area is certified by both FSC and PEFC. About 12% of the managed forest area in North America is FSC certified and 27% is certified by PEFC endorsed schemes. In North America, the following PEFC endorsed schemes are active: Canadian Standards Association (CSA), Sustainable Forestry Initiative (SFI-FM) and the American Tree Farm System (ATFS).

Depending on the final destination, CSA, ATFS, and SFI-FM fibers are either integrated into the COC of PEFC International for overseas markets in Europe or via SFI Fiber Sourcing (SFI-FS) for the domestic markets in the US and Canada. Via the SFI-FS, together with a state-wide coverage of Best Management Practices (BMPs), organizations can show that their raw material comes from legal and sustainable sources in North America, and whether the forests are certified or not. If fibers come from uncertified lands in North America, SFM must be promoted through standard requirements (Objectives 8 to 20), such as landowner outreach, logger training, and research activities [41]. SFI-FS has a smaller scope than SFI-FM, as the forest part ("forest land management objectives 1–7") is excluded [42]. SFI-FS products can contain a mix of fibers from SFI-FS, SFI-FM, CSA and ATFS.

2.1. SFM Schemes in North America (Supply Side)

Forest legislation in a country or region is most important for any kind of forest certification, often one of the principles in a forest management standard and the first item to be checked by the third party auditor. In both the US and Canada, dedicated national or regional legislation provides mandatory rules for sustainable forestry management on a macro level. For example, in British Columbia (BC), the legislation and regulations consist of more than 50 legislative acts, applicable for SFM [43]. Examples of SFM topics covered by BC's province law are: harvesting level, reforestation, forest conversion, illegal logging avoidance, old growth management, public participation and community involvement [44]. Further, BMPs are applicable for all kinds of harvesting operations, from planting to final felling of trees [13]. In the US, the BMP's are introduced state-by-state, and include a dedicated set of guidelines. For example, Georgia prescribes that snags, dead and down woody debris, brush piles, or windrows throughout harvest areas should be left on site for wildlife management purposes [45]. In addition, in the case of extra woody biomass (slash) removals, Biomass Harvesting Guidelines (BHG) can be integrated in the BMP, as practiced in some US states [46]. BHGs are not a common tool for Canadian forests [47]. See Appendix D for more specified, regional characteristics regarding forest legislation, applicable for the North American forests.

On top of this national legislation (or instead in countries without forest legislation), voluntary SFM certification (on FMU level) is relevant for compliance with sustainability requirements for bioenergy. Amongst others, SFM includes the requirement to include forest management plans with long-term harvesting goals, replanting practices, prescribed impact assessments for harvest, *etc.* The land managed according to the standards for SFM can be divided into areas with certificates for sustainable land use (such as those applied by FSC-FM, SFI-FM and CSA) or downstream certificates for sustainable sourcing (like FSC-CW and SFI-FS). Both approaches have generic principles, which are applicable for more countries or regions [48–50]. Criteria and indicators, however, are mostly country or region specific and are laid down in national or regional specific standards or initiatives.

2.2. Evolving Public and Private Strategies in the EU for Sustainable Biomass (Demand Side)

On the demand side, we considered the UK as EU's latest frontrunner with its requirements as a likely basis for possible future binding criteria for the EU's 2030 climate and energy policies [51]. The UK is actually the first Member State that has combined legality requirements with sustainability criteria [52]. Its renewable energy policy states that (international) imports will play a role alongside domestic supplies [32]. The UK has become the EU's main destination for overseas woody biomass imports [23] after the Netherlands and Belgium started to close their subsidy schemes from 2012 [53]. Most of the woody biomass traded to the UK is in pellets: about 1.3 million tons in 2012, mostly supplied by Canada and the US (see Table 1). Other EU member states have also set up their own national sustainability schemes for woody and agricultural biomass, which are not necessarily complementary or compatible [9]. The latest developments in the private sector reflect the desire to develop one harmonized European system, set up by the European energy sector and complementary to those set up by the respective public sectors. The following sub sections give a more detailed picture of the latest developments.

Table 2. Forest areas worldwide [54,55] and updated forest certification [56,57].

Region	Total Forest Area (in Million ha)	Managed Forests * (in Million ha)	Change in Total Forest Area 2000–2010 (in %)	Certified Forests of FSC per February 2014 in Million ha [56]	FSC forest Areas in % of Managed Forests	Certified Forests of PEFC per March 2013, in Million ha [57]	PEFC Forest Areas in % of Managed Forests
Africa	674.4	186.0	−0.49	6.7	4%	0	0%
Asia and the Pacific	740.4	230.5	0.19	11.4	5%	14.6	6%
Europe	1005	844.2	0.07	80.0	9%	77	9%
- Russia	809.1	703.9	-	38.7	5%	0.5	0%
- EU-28	130.4	99.1	-	31.7	32%	67.9	69%
Latin America and the Caribbean	890.8	83.4	−0.46	14.1	17%	3.2	4%
The Near East	122.3	46.3	0.07	0	0%	0	0%
North America	679.0	554.0	0.03	69.1	12%	149	27%
- Canada	310.1	294.6	0	54.43	18%	113.5	39%
- USA	304.0	228.0	0.13	14.1	6%	35.3	15%

* Managed forests are defined as total forest minus protection forests, conservation forests and social services.

2.2.1. National Policy Schemes on Sustainability of Solid Biomass

Denmark and Sweden started using wood pellets and chips in the 1980s in the medium scale district-heating sector to replace fossil fuels. The main market drivers were fossil fuel taxes, plus public decrees forcing large-scale power utilities to use biomass. The first legislation in this area only required that wood pellets must be produced from clean wood without any kind of contamination [58,59]. Thus far, the Scandinavian countries have not specified more specific sustainability criteria.

Belgium set ambitious targets for renewable large scale electricity production in 2005 [60]. Sustainability of energy is regionally organized in Belgium and verification systems were implemented in three regions (Brussels, Flanders and Wallonia). Sustainable wood sourcing can be proven via forest certificates such as FSC (mostly practiced in Flanders), PEFC (Wallonia), or the corresponding SFM certificates downstream. In absence of such certificates, a periodic independent written review of the forest management or a documented field visit (spot-checks) is needed in the country of origin.

Over the same period, Dutch power utilities started to use woody and agricultural biomass. The Dutch NEN organization initiated the NTA8080 for the sustainable production and import of biomass for energy conversion and biofuels. The most common SFM issues are integrated in the NTA8080, such as social, ecological, and economic impacts on a FMU level. In addition, macro topics like competition with food production are assessed on a regional or country level. To facilitate this latter assessment, the Dutch expert group on sustainable biomass [61] has proposed the compilation of a green list with the permitted types of solid biomass feedstock, such as wood waste and industrial residues. The NTA8080 has been mostly applied for production within the Netherlands and less for the import of biomass [62].

In 2004–2005, the UK government developed a public procurement service for wood and wood products, called Central Point of Expertise on Timber procurement (CPET) [33] as a response to the sustainable forest principles of the Rio Summit in 1992. Anticipating possible criteria for solid biomass [9], the UK Government drafted legislation for legal and sustainable biomass sourcing in 2012 [32]. This UK draft legislation will be embedded in the Renewables Obligation (RO). To avoid unnecessary regulation [32], the UK government has proposed that sustainability criteria in the RO should be fully based on the CPET policy for wood products [33], including the latest changes to prevent illegal harvesting (EUTR) [34]. UK's power and heat generators have three reporting obligations to illustrate their sustainable use of woody biomass under the RO umbrella [32]: (1) life cycle GHG performance, (2) land criteria or no-go areas and (3) profiling criteria.

As our sustainability check (in Section 4 benchmark results) was actually triggered by UK's biomass regulations (Section 1), we briefly highlight the three criteria. Firstly, to evaluate the total lifecycle GHG emissions of electricity production using woody biomass, the compilation should include the cultivation, processing, transport, and any direct land use change effects associated with the use of the biomass. The UK currently requires that biomass has to meet a target of 60% GHG reduction (285 kg CO_2eq per MWh), progressing towards 75% in 2025 [52]. The UK is developing an interactive land use and bioenergy tool [63] that could provide more information on overall GHG savings or emissions related to the most common bioenergy pathways from source to end user: it could support discussions around carbon accounting methodologies [32]. Secondly, confirmation is needed that the woody biomass is not sourced from land with high biodiversity value, including primary forest or areas designated by law for nature or environmental protection purposes. In addition, the biomass should not be sourced from land

with high carbon stock value, including wetlands, continuously forested areas, or (undrained) peat lands. One of the main remarks from stakeholders to the UK's draft legislation is that the required evidence to demonstrate compliance with RED Land Criteria is difficult and costly to obtain, and has little relevance for ensuring that forests and woodlands are managed sustainably [32]. Instead of copying the RED criteria, complementary SFM schemes, such as the Forest Stewardship Council (FSC) and the Program for the Endorsement of Forest Certification (PEFC), have been introduced in the draft legislation for compliance with the "land criteria". FM certification (FSC-FM, CSA and SFI-FM) are called Evidence A and supplementary risk based assessments or downstream certificates (FSC-CW, SFI-FS) are referred to as Evidence B [64]. The UK government assumes that those SFM schemes meet the "spirit of the RED", and ensure that biomass is sustainably sourced. The third reporting requirement is related to the profile of the woody biomass: type of material (logs, residues, and pellets), volume/mass, and country of origin of the biomass. The profile needs to be earmarked per ship-load of wood pellets, lorry-load of chips, also called "consignments" [34] and is relevant for EUTR compliance (Section 3.1).

2.2.2. Private Certification Schemes by the Energy Sector

The market advantages of one international, harmonized system of sustainability criteria for sustainable biomass are obvious: the wish for easy inter-trading of sustainable forest biomass (e.g., pellets) between different end-users within the energy sector, and less administrative burden due to different systems. Until 2013, there were three large scale consumers of industrial wood pellets for power production in EU-28: Electrabel (Belgium), RWE Essent (the Netherlands, UK) and Drax (UK). All developed their own industry label for sustainable biomass.

Electrabel makes use of a private label, developed by Laborelec for Belgium. This label is a specific verification procedure for imported biomass in Belgium [60]. It applies similar audit procedures for the Flanders and Wallonia regions, gathering the legal requirements for the import of biomass to the power plants in both regions. Per load of biomass (shipment), an independent inspection body (SGS) verifies biomass origin and energy calculations [65]. The requirements for the biomass origin, in order to become accepted under the Belgium label, are laid down in one single document. This is called the "Supplier Declaration", and needs to be signed by each supplier in the biomass chain. The energy calculations are based either on GHG savings (Wallonia) or on the reduction of fossil energy sources (Flanders).

The largest Dutch user of biomass, RWE Essent, has developed a biomass certification system, called Green Gold Label (GGL), together with another certification body (CUC) [60]. This development started in 2002 and involves a track and trace system for all kinds of biomass between biomass processing units (like pellet plants) and the European power plants. This system is based on transaction documents for each new stage in the supply chain: pellet plant, external storage, shipments, power plant. Another major GGL component is the check of sustainable fiber input and output via a mass balance system. GGL accepts certificates issued by FSC, PEFC endorsed standards (CSA, SFI-FM, ATFS) and SFI-FS [66]. See also Appendix C. In this system, contamination with non-biogenic or environmentally harmful materials is prohibited. GGL has extra safety and health guidelines for the manufacturing and transportation stages.

The corporate policy of Drax aims to ensure that the biomass used in their UK generation facilities can be verified as legally produced and environmentally sustainable. As a minimum it needs to comply with a set of sustainability requirements based on the regulatory initiatives of the UK [32], European Union [9], and other, market based initiatives. Therefore, Drax is developing a new framework with internationally recognized standards and principles for procurement of woody biomass. The independent auditing from forest to power plant will result in public summaries over time [67].

Currently, a new overall solid biomass framework for Europe's energy sector is under construction: the Sustainable Biomass Partnership (SBP), formerly known as Initiative Wood Pellet Buyers (IWPB). The SBP is a working panel consisting of major European utilities using woody biomass (pellets, chips), plus two certification bodies SGS and CUC. It is planned to become operational in 2015. The goal is to work towards an integrated standard for sustainable and legally harvested biomass [68]. The UK is one of the main markets, and therefore the new standard has a strong orientation towards the UK draft legislation for biomass use [68]. The new standard has been set up from the existing frameworks of power companies [65–67] plus the RED principles for liquid biofuels [1]. The SBP is supposed to be a downstream certification system, starting from a pellet production plant or wood chip processing unit. From the pellet plant downwards, the certification should cover storage, transport, and energy conversion stages. Next, there is an upstream risk assessment for the raw material suppliers of the pelletizing plant, either sawmills or forest contractors. Risk assessments will be performed on a random spot-check basis. To avoid unnecessary regulation, the SBP shall further cover the newly the EUTR policy for wood products with tracking and tracing back to the forest origin [6] and also EC's recommended sustainability criteria [32–34]. SFM certificates (e.g., FSC; PEFC) are supposed to cover most of these sustainability requirements, with any remaining aspects to be separately audited under the SBP umbrella.

2.3. Industrial Wood Processing Residues versus Post-Consumer Wood Waste

Post-consumer wood waste has separate (draft) legislative requirements and is also separately incorporated in the respective SFM frameworks. The EU Timber Regulation exempts the post-consumer waste wood from any obligations, whereas by-products (e.g. processing residues) should be monitored in the same way as other harvested wood. In the case of wood products like particleboard, which is partly made from waste fibers and partly from virgin fibers, EUTR compliance needs to be demonstrated for the virgin fibers only. The 2010 Communications [9] currently considers the sustainability risks of both wood waste and residues as low when it is related to domestic (EU) biomass production where no land use changes occur. However, the expected increase of demand for domestic and non-EU biomass feedstock may have its impact on carbon stocks in forests and agricultural land and soils. Following the risk expectations, the UK has only exempted post-consumer wood waste from the reporting requirement on land use; there are no exemptions for industrial wood residues [32]. Nevertheless, the UK procurement policy requires recycled timber products (post-consumer wood waste) to be supported with evidence tracing the timber back to the previous use, rather than the forest use [33]. In case of GHG life cycle reporting, residues and post-consumer wood waste are treated in a similar way by the UK [32]. Post-consumer wood waste, forest residues and industrial-processing residues shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials. For

example, the requirements to report on GHG lifecycle emissions need to start at the harvesting stage for forest residues, at the sawmills for sawdust and at the waste collection points for waste wood [69,70].

In the slipstream of the common SFM scope (virgin fibers from managed forests), the distinction between "(processing) wood residues" and "(post-consumer) wood waste" should be remarked on. In current certification practices, the production and the use of post-consumer wood waste products is exempt from any certification requirements only when the minimum input of the recycled fibers reaches at least 85% post-consumer wood waste within FSC [37,71] and 70% within PEFC schemes [72], respectively. When its recycled fiber share is lower than the respective thresholds, the remaining part has to comply with SFM principles. Practically, with a share of 69% recycled fibers, only the virgin fibers (31%) of that wood product need to be assessed against the full set of SFM principles.

3. Methodological Framework

Whereas the EU's 2010 communications [9] are focusing on sustainability issues for all kinds of solid biomass for energy (Section 3.2), the EUTR [6] is primarily set up to prevent illegal harvesting of trees (Section 3.1). We have included EU's Waste Directive [73], which is relevant for post-consumer wood waste (Section 3.3). These sections are the basic ingredients for our benchmark set-up in Section 3.4.

3.1. Legal Harvesting: EU Timber Regulation (2010/995/EC)

The new EU legislation to prevent illegal logging of forests (EUTR) [6] provides obligations to operators who place timber and timber products on the EU market and traders that distribute the products. It covers a broad range of wood products including wood chips, pellets, and other products. Traders or operators in the EU have to set up a due diligence system (DDS), where the wood products enter into the EU internal market for the first time for distribution or use in the course of a commercial activity. So-called "Monitoring Organizations" (MO), as approved by the European Commission, will check the DDS and its procedures at least once per year. The EUTR consists of three components: monitoring of wood products (also called "access to information"), risk assessment and risk mitigation.

The monitoring starts with the requirement to establish a due diligence system (DDS) to safeguard the legal harvesting of wood resources. Basic documents are custom declarations and trader or operator specific documents, stating the volumes of wood traded, the wood species, the forest management unit (FMU) of the wood resources and the legislative documents for forest ownership. In addition, the country of harvest can be classified by a Corruption Index, which may lead to extra documents on top of the basic ones. This index is linked to the public sector of a country and serves as a resource to assess the risks.

The involved MO's shall verify the proper use of the DDS and take appropriate action in the event of failure by the operator or trader to do so. Although no EU requirements exist about what risk assessment method shall be used, the involved MO's may set up an inventory of non-conformities (NC's). Similar to SFM certification procedures, the inventory can be based on interviews with the operators and traders, plus a check of all kinds of relevant items. For example, a global check of transaction documents should confirm the status of the product (e.g., tree species, volume) and its transfer throughout the supply chain, starting from the first supplier to at least the first entry point in the EU.

In exceptional circumstances (risk assessment with major deficiencies), operators and traders will have to deal with risk mitigation procedures. Risk mitigation becomes applicable when wood trade flows are sourced from forest areas where illegal harvesting activities could have occurred. On demand of the competent authorities in a Member State, on-site inspections at the operator's premises are organized by the MO's, plus possible surveillance visits to the forest (source of wood origin). The competent authority of a Member State should be notified only when illegal activities are confirmed or repeated failure to improve the situation of NC's. After notification, the authority can either give substantial fines to operators or traders involved in illegal logging, or order seizure of the goods.

There are two exceptions for not setting up a DDS: wood with a CITES (Convention on International Trade in Endangered Species of wild fauna and flora) permit and wood sourced from countries that have a VPA (voluntary partnership agreement) with the EU (such as Indonesia or Cameroon). The VPA generally consists of a national monitoring system of legal harvesting practices. Thus far, only countries with tropical forests are involved in setting up VPA agreements with the EU. In addition, the US has included the Lacey Act to control and limit the illegal trade of wood and paper products. Generally, this law aims for extra protection of trees against illegal logging and makes any illegal timber trade punishable by law [74]. It is prescribed that all operators exhibit due care and implement DDS in order to minimize the risk of illegal wood entering supply chains. Florian *et al*. [75] observed a growing consciousness of the Act in the private sector, but also that official guidelines were lacking. The US Lacey Act assumes more private self-regulation than the EUTR [76]: all kinds of expert organizations may assist timber companies with setting up and implementing the US equivalent of DDS [77].

3.2. Sustainable Sourcing: EU's 2010 Communications

The Commission has recommended in its 2010 Communications [9] that EU Member States that either have, or who introduce, national sustainability schemes for solid and gaseous biomass used in electricity, heating and cooling installations, provide that these in almost all respects are the same as those laid down in the Renewable Energy Directive (RED) for liquid biofuels [1]. This minimizes the risk of diverse and possibly incompatible criteria at a national level. In addition, the use of domestic raw material must not be favored above imported material; *i.e*., there should be no allowance of trade discrimination [78]. Within this discussion, some of EU's major stakeholders have called for more harmonization on this topic, but the involved stakeholders have diverging ideas on how to progress.

Forest owners organized in the CEPF (private forest) and Eustafor (state forest) strive to increase both sustainable production and mobilization of forest biomass under current legislation and SFM frameworks. European forest owners expect consistency for any additional criteria for solid biomass [79]. In this respect, the EC has offered to avoid excessive administrative burden and exempt small scale forest holdings [80]. This may open the door to, for example, (i) group certification; e.g., a group of forest owners (or contractors) can be audited on a sample basis instead of an audit over the whole area; (ii) certain thresholds applicable for minimum certifiable forest areas, similar to the one (1 MW capacity) imposed for heating purposes (such as district heating using chips). Both "doorways" may also be viable for the US forest sector, which includes a relatively large amount of small land owners.

The European pulp and paper industry (represented by CEPI) is a major user of wood in the forest sector. CEPI's members have committed themselves to legal and sustainable sourcing via independent certification systems [81]. CEI-Bois (wood working industries) also supports the Commission's efforts, but refers to EU's green public procurement [82] as a starting point. In the specific case of saw mills, the competition of energy wood with local markets needs attention [8,83]. The proper use of high quality logs (trees with a diameter dimension >15 cm) for construction, needs explicit safeguards; *i.e.*, "cascading priorities" [35,84], similar to waste wood fibers. In this respect, the UK government expects that the higher market price for high quality saw-logs will prevent their use in power generation [32].

Six large European power utilities have initiated their own measures. They developed draft SBP requirements (see Section 2.2.2) for pelletized and other biomass such as wood chips, which can be sourced from certified and non-certified forest areas and plantations [68]. Their voluntary approach can be substantiated and finalized by a legal EU framework. Together with the biomass processing sector, the energy sector wish to have harmonized, binding criteria for solid biomass at EU level [85].

From the perspective of Non-Governmental Organizations (NGO's), the exclusion of social criteria in the EU's 2010 Communication [9] is a major topic of concern. Although social criteria are not obligatory for the procurement specifications of biomass, they are recommended in the UK. As such, they are supposed to be covered via voluntary certification systems for forest management (Evidence A) or separately covered via risk based assessments of Evidence B [33]. See Appendix B for the Evidence B criteria. Note that the inclusion of environmental and social criteria in the legislation is often stated to be difficult [86], as global trade rules prohibit "discrimination" against products from specific countries.

3.3. Cascaded Use: EU's Waste Directive (2008/98/EC)

The EU Waste Directive (2008/98/EC) [73] is relevant: this EU law prescribes a certain hierarchy for waste, in which cascading should be promoted. Harvesting and industrial wood residues are not regarded as waste and thus not subject to the Waste Directive. Post-consumer wood waste is considered a waste and therefore needs to follow the waste hierarchy. Where possible, post-consumer wood waste should be re-used or recycled after end of life, before using it is a feedstock for energy applications. Certain specified waste" shall cease to be waste after it has undergone a recovery operation, including recycling (article 6 of the Waste Directive). The re-use of discarded wood products or the recycling of waste fibers into other products is prioritized (cascading), when those processes have no adverse environmental or human health effects. Waste wood is not yet used for pellet production. Although the use of clean waste wood (A-grade) for pellet production is technically possible, the rules in the EU Waste Directive are unclear about the shipping of clean waste wood across the EU borders. A pilot project in the US learnt that such pellets can be only imported by the EU with certain restrictions. Either the US pellet manufacturers or the EU pellet traders shall have to comply with rather strict administrative procedures [87] at the EU Member States' authorities [69,70], similar to the import of waste wood from chemically pre-treated wood, like railway sleepers and other outdoor products with chemical preservatives (C-grade).

3.4. Benchmark Compilation

Our benchmark consists of one dimension consisting of the EU's (draft) legislation and another dimension consisting of voluntary certification. For the first dimension, we have combined sustainability criteria from the set of (draft) legislation described in Section 3.1 through Section 3.3. We started with the EUTR and its requirement to have a DDS for both domestic sources and for import to the EU-28 [6]. According to the EU, operators and traders need to guarantee that the upstream supply of wood resources is fully traced back to their origin, and the wood legally harvested. For our benchmark, the EUTR is reduced to one basic criterion: "Prevention of illegal harvesting practices". Further, the adoption of the Waste Directive is incorporated and this is also limited to one criterion: "Cascading of post-consumer wood waste". Finally, a number of possible relevant sourcing requirements for woody biomass are formulated, supported by the topics in our Introduction Section plus related guidelines from varying references (see details below). Our compilation has resulted into one overarching set of six key criteria, of which A through E are also referred to in EC's 2010 Communications [9]:

A "Greenhouse gas (GHG) calculations" for activities in the solid biomass supply chain. This aspect is also incorporated in the RED for liquid biofuels [1]. In our benchmark we have limited it to GHG effects from forest operations, due to the forest management scope in the SFM frameworks.

B "Safeguard of forests with high biodiversity. This no-go area is also incorporated in the RED for liquid biofuels [1]. Specifically, we have inventoried the protection of primary forest areas, along with specific safeguards for the sensitive undisturbed forest areas in North America, called old growth forest or intact forest landscapes. Other areas designated by law for nature or environmental protection purposes [32] are not regarded in our benchmark.

C "Safeguard of forests with high carbon stocks and areas such as wetlands and peat lands". These no-go areas are also incorporated in the RED for liquid biofuels [1].

D "Sustainable harvest rates" (or maximum levels for annual allowable cuts). We focus on intensive harvesting practices, as EC's 2010 Communications state that a number of other practices can result in a significant loss of both terrestrial carbon and significant changes in productivity. Examples are harvesting practices that result in excessive removal of litter or stumps from the forests [18]. Next the final harvest conditions are relevant: large felling areas, without adequate provisions for regeneration, often remain understocked (less carbon) after clear-cutting [88]. Therefore the clear-cutting area is also considered in our inventory.

E "Preventing deforestation", with a focus on forest management plans and post-harvest guidelines that include regeneration and replanting practices. EC's 2010 Communications also state that deforestation and forest degradation can result in a significant loss of both terrestrial carbon and significant changes in productivity. Indirect land use change (iLUC) effects are not included: its quantitative evaluation is difficult and there is not yet any scientific consensus [89–93].

F "Exceptional removal of dying or dead trees", related to both managed and non-managed forests. Sustainable harvest rates (see criterion D) are elaborated for the long term, in which exceptional circumstances are not accounted for. Therefore, we added the exceptional removal of dead or dying trees after natural disturbances (criterion F); these so called "salvage logging" operations may affect both biodiversity and carbon stocks [22,26].

For the second dimension, the most frequently used SFM frameworks in boreal and temperate forests in North America are selected. We have divided the SFM frameworks into FM schemes, and risk-based assessments. The risk-based programs are complementary to the forest management (FM) programs, and allow for the mix of fibers from certified FM areas with those from non-certified FM areas. To illustrate the share of the FM *versus* the risk-based programs, Appendix C shows the 2012 shares of all biomass for energy certified within the Green Gold Label [94]. GGL is one of the major sustainability programs for international biomass trading by the energy sector. The risk-based options are most practiced within the GGL program: FSC-CW has a major share (30% for logs and residues together) and SFI-FS has a total share of 26% in the total biomass certification program of GGL. The forest management options have shares of 21% (SFI), 6% (FSC), and CSA (5%).

We started our benchmark with four FM frameworks, adopted by the UK for its sustainable biomass import scheme [33]. Those are referred to as "Evidence A" options (see also Section 2.2.1). The selected frameworks and related documents are:

1 FSC Global forest management [37,95]. Next to the worldwide set of FM criteria, we have selected British Columbia (BC) to illustrate the reach of regional FSC standards [96]. BC is one of the largest pellet producing regions and a main supplier for the EU markets [24];
2 PEFC International [97] maintains a generic FM standard. This is used as a benchmark that national forest certification need to be in compliance [98] with, in order to achieve PEFC endorsement;
3 SFI Forest Management 2010–2014 [42,99];
4 CSA Z809 [100];
5 ATFS 2010–2015 [101]. We added ATFS as another option ("miscellaneous"). It is not included in the UK scheme as Evidence A, but this FM option is currently used for international biomass trade under the GGL umbrella. It had a 4.5% share in the GGL trade in 2012 (see Appendix C). ATFS usually certifies wood plantations, whereas our sustainability benchmark is applied to all forest types;
6 WWF Gold Standard [102]. In addition, for a few of the criteria, the WWF-GS) is also evaluated as "miscellaneous". In 2013, WWF enlarged its international GS program with CarbonFix projects, those are certified forest plantations in combination with carbon credits.

We have inventoried a few alternative biomass sourcing frameworks (without FM certification), to be used for remaining fibers. Their classification is based on existing risk based assessments in the UK, where they are qualified like Evidence B [32]. FSC-CW and PEFC-DD are both complementary to their respective FM frameworks, with a focus on EU and US regulations to prevent illegal sources. For more detailed information, see Section 3.1.

7 FSC Controlled Wood (FSC-CW) [103,104];
8 PEFC Due Diligence (PEFC-DD) [72];
9 SFI Procurement, also called SFI fiber sourcing (SFI-FS), and limited to SFI Objectives 8–20 [42].

The compliance of the EU frameworks on the one hand (first dimension) and the SFM frameworks *etc.* on the other hand (second dimension) is elaborated via 3 coverage grades: (1) sufficient coverage or explicit intentions to do so; (2) partly sufficient; *i.e.*, the topic is not fully incorporated in the SFM program or it is not sure how this topic will be covered via ongoing (stakeholder) consultations; (3) an insufficient coverage. These categories were originally defined after an extensive screening of the actual audits for sustainable biomass production and trade, under the GGL program based in the Netherlands. This kind of screening is a common procedure for the Dutch accreditation body to check the performance of certifying organizations. The screening procedure was limited to the eligibility of wood pellets and wood chips trade to Europe by GGL enterprises, which are using existing SFM certificates of FSC, FSC-CW, CSA, SFI, SFI-FS and ATFS. Apart from internal feedback within the GGL Foundation (such as quarterly advisory board meetings), two additional feedback sessions with each of the main forest certification programs operating were organized (see Acknowledgements), to fine-tune the outcome of the screening. In some cases, we consulted extra documents, such as publicly available summaries of CSA and SFI forest audits, to get more insight into the certification practices.

4. Benchmark Results

Table 3 shows the summarized results of the benchmark of EU (draft) legislation with voluntary SFM frameworks. Benchmark details for sustainable sourcing via forest management certification (FM fibers) and risk assessments (risk based fibers) are given in Appendix D1 and D2 respectively.

The selected sourcing topics are well covered only via FSC and PEFC International [105], two of UK's approved certification schemes for FM [32,33]. SFI-FM, another recognized UK scheme, lacks coverage for salvage logging, whereas CSA has only partial coverage for most items. Possible GHG savings calculations and especially the safeguard of high carbon stock forest areas are not sufficiently covered by any of the FM frameworks. Note that ATFS, the "miscellaneous FM option" in North America, has an insufficient overall coverage. This is caused by ATFS' scope: small private forest owners, including relatively young forest areas established by farmers. The sourcing topics of ATFS are generally applicable to these young forests, except for the topics of wetland protection and salvage logging, which are more relevant for older forests. Finally, the new WWF GS standard (another miscellaneous option) may be a valuable tool for the other SFM frameworks: so far, the GS encourages dual certification with the FSC program; thus all topics are covered in the same way. In particular, the indicator "Applicability" looks promising as a safeguard of high carbon stocked forests. The WWF GS states that the project area shall not be on ground with permafrost, not be on wetlands, soil disturbance shall be lower than 10% of the total project area and organic soils shall not be drained.

With regards to the risk based assessments [32], FSC-CW and PEFC-DD have an insufficient coverage of sustainable sourcing topics, except for high biodiversity forest and preventing deforestation. In the case of the SFI-FS program, there is an evident risk for non-sustainable fibers, due to its different provision of track and tracing at state level. This means less detailed information to prove sustainability in North America, as opposed to the FMU level for the FM program(s). SFI-FM program participants shall include efforts to promote conservation of biological biodiversity. However this criterion is limited to domestic fibers from North America and not applicable for non-domestic fibers from outside North America. This exception leaves a risk for fibers from illegal sources and no-go areas sourced outside

North America and the possible mix with the domestic fibers into one product. Consequently, these high risk fibers can be inadvertently included in the SFI-FS trade flows in North America. Export to Europe and consumption in European power plants is also applicable for the current supply chain under the GGL program, as SFI-FS is an approved system. Use for wood product export to Europe is not applicable, as SFI-FS is not endorsed by PEFC International chain of custody.

Finally, the main principle of EU's Waste Directive is inventoried for our benchmark. Despite their commitments to legal harvesting and sustainable sourcing, the PEFC and FSC frameworks have not prescribed any cascading principles for wood-waste material. The coverage of the Waste Directive is insufficient.

Next to the benchmark, our in-depth investigation of state-of-the-art certification procedures in North America resulted in two major observations. Firstly, we learnt that measurable indicators should be completed and implemented before the start of the independent audit stages. An example is the public consultation in Canada, which is extensively organized for forest managers and other interested parties in Canadian forest stewardship plans. The extensive public consultation results in the development of main indicators for frameworks, such as the Canadian Standards Association (CSA), SFI, and FSC [106]. However, the CSA standard distinguishes "core indicators" and "discussion items" [100]. Both indicators are including in a SFM audit for forest and forest industries. However, whereas the CSA core indicator is an obligatory default value during the audit, the CSA discussion item can be evaluated again with stakeholders consulted at the start of an audit. In the latter case, the indicator is not necessarily implemented in the consecutive stage of the audit.

Secondly, the EU-28 uses other definitions for primary forests than those used in North America. Definitions of old growth forests or intact forest landscapes [96] are commonly used in the Canadian forest sector to cover the legal protection of high biodiversity forests. The EU for term "primary forest", as defined by the FAO [1], is not utilized in the context of Canada's own regulations, and is not reported as such in provincial or federal land and forest inventories [107]. Canadian forests can be categorized into "managed" *versus* "unmanaged". The exact definition of managed forest varies from province to province. Consequently, the managed forest is not equivalent to a forest area that has been, or is planned to be, actively managed for timber production. In addition, the unmanaged forest is not meant to reflect a primary, virgin or protection status [107].

Table 3. Benchmark for legal harvesting [6], sustainable sourcing [9] and cascaded use [73] of woody biomass for energy in the EU: their coverage through sustainable forest management (SFM) programs in North America.

	FM systems						**Risk based systems**		
	Certified biomass via programs for certified forest management areas (UK Evidence A)				**Miscellaneous options**		**Complementary programs (UK Evidence B)**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	FSC Forest Management	PEFC International forest management	**PEFC Endorsed Forest Management frameworks** SFI forest management	CSA	ATFS	WWF Gold Standard **(complementary to FSC FM)**	FSC CW Controlled Wood	PEFC DD Due Diligence	SFI FS Fiber sourcing (wood procurement)
I. Legal sourcing: EU Timber Regulation (EUTR)									
A. Basic compliance: prevention of illegal harvesting practices	√	√	√	√	√	√	√	√	*X*
II. Sustainable sourcing: EU Communications (2010)									
A. GHG for forest operations, anticipating a GHG savings requirement	*X*	*X*	±	±	*X*	±	*X*	*X*	±
B. No harvest from high biodiversity areas, incl. primary forest	√	√	√	±	√	√	√	√	*X*
C. No harvest from high carbon stocks or from wetlands	±	±	±	*X*	*X*	√	*X*	*X*	*X*

Table 3. *Cont.*

	FM systems						Risk based systems		
D. Sustainable harvest rates and carbon stocks	√	√	√	±	±	√	*X*	*X*	±
E. No deforestation (and natural regeneration and replanting practices)	√	√	√	±	*X*	√	√	√	*X*
F. Exceptional recovery of salvage trees (after natural disturbances)	√	√	*X*	±	*X*	√	*X*	*X*	*X*
III. EU Waste Directive (post-consumer waste)									
A. Cascaded use of harvested wood products	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Legend for the coverage of topics for legal and sustainable sourcing									
√ = sufficient coverage via SFM or other programs (or explicit intentions)									
± = partly sufficient: this topic is not fully incorporated or it is not sure how any (stakeholder) consultation will fully cover this item									
X = coverage is insufficient									

5. Discussion

As well as the benchmark coverage by SFM certificates in the previous section, we found three overarching developments to be critical for the legal and sustainable sourcing of biomass for energy. Respectively the mass balance approach, used for current UK biomass policies (Section 5.1), adaptation to new developments (Section 5.2) and forest carbon accounting (Section 5.3), are highlighted hereafter.

5.1. Mass Balance Approach

A variety of strictly certified, less strictly certified and even non approved fibers [108] may usually be mixed in the early stages of the supply chain (e.g., pellet plants, storage units, *etc.*). A physical separation at the end seems difficult to implement. The UK proposes to use the mass balance for all stages in the downstream wood supply chain; biomass processing, storage, and energy conversion [32]. This approach enables "consignments" (see Section 2.2.1) to have different types of certificates and the biomass fibers to be physically mixed at any point in the chain. This is a common approach to account for the sustainable input and output flows in a certain stage, e.g., applied for wood products certified by FSC or PEFC [72,104] and for liquid biofuels in the EU's RED schemes [1]. In the same way, woody biomass sourced from certified forest areas and from non-certified forest areas can be tested for deliveries to an UK energy plant [32]. Two types of evidence are respectively regarded: one is related to the level of FMUs, *i.e.*, certified forest area's (Evidence A); the other one is related to risk assessments in the upstream supply chain (Evidence B), as regarded from UK's point of view.

- √ The main Evidence A type accepted for compliance with UK's draft law should be the approved forest management (FM) schemes of FSC or PEFC International endorsed schemes. Therefore, far, two PEFC endorsed schemes in North America are allowed by the UK: CSA and SFI FM [32,33]. The compliance with the EU's draft legislation is sufficient for FSC-FM and SFI-FM, except for prevention of sourcing biomass from wetlands. In particular, CSA lacks sufficient guidance for this topic, and unwanted biomass sourcing may occur. Further, the topic of salvage logging is not yet embedded in SFI's forest management, which can lead to possible excessive recovery of dead trees, instead of leaving them as a key biotope for wildlife. Finally, ATFS (a PEFC endorsed scheme) is not approved by the UK for Evidence A [33]. Therefore, ATFS fibers cannot actually be regarded as FM certified fibers [108].
- √ Other Evidence B is allowed, if Evidence A is not available [64]. The information needed for Evidence B to be eligible is indicated in Appendix B, with three draft checklists of information items that should be made available regarding legality, sustainable sourcing, and supply chain control. The UK suggests FSC's controlled sources (FSC-CW) and PEFC's avoidance of controversial sources (PEFC-DD) and SFI-FS. The remaining 30% shares from FSC-CW, PEFC-DD and SFI-FS showed insufficient coverage of EU's draft legislation on legal harvesting, sustainable sourcing and cascaded use (Table 3). Specifically, the SFI-FS system is a matter of concern. SFI-FS certified woody biomass can consist of high risk fibers (controversial sources), especially when the biomass is sourced from outside North America. Neither of those systems can in itself be accepted for 100% under the UK law. However, they can be partly used;

information and evidence B should be provided to demonstrate the wood is legally and sustainably sourced and traceability documents are met [64].

The following situations can occur:

A Current situation. Following Section 2.2.2, individual certification or verification systems exist per energy company: Laborelec, Drax' and GGL procedures. For example, GGL accepts different SFM certificates. Some of those certificates can be regarded as insufficient to comply with current EU's (draft) legislation in our benchmark (Section 4). When the companies purchase their pellets from the same supplier and (unintentionally) claim the same part of sustainable fiber input and output (via an independent mass balance check), there is no safeguard to prevent the remaining share of non-suitable fibers (either non-approved fibers or abundant risk-based fibers) from flowing into the EU market. Actually, the mass balance becomes a less suitable tool, in case all EU's (draft) legislation for legal harvesting and sustainable sourcing has to be fully complied with. If full compliance with this legislation is required, we think it is crucial to have one cross-reference procedure in place by certification bodies (see further the Recommendation Section).

B Near future situation (2015 onwards). UK's requires to have minimum 70% Evidence A and maximum 30% Evidence B certificates at the final end of the supply chain, when biomass is delivered to the site of an energy plant. The UK requirements will start in 2015. This approach was already initiated by the main SFM programs, after immediate action was required after the launch of the EUTR for legal sourcing in 2013 and there were not enough FM fibers available on the market. A large share of managed (production) forest areas is currently not certified; the risk approach is used by suppliers to comply with legal sourcing requirements (EUTR, Lacey Act) to a maximum of 30%, in line with common used certified SFM labels as "FSC Mix 70%" [71] and "PEFC certified" [109]. Both labels allow mixed fiber contents in wood products for marketing purposes, when at least 70% of the fibers originate from certified forest areas. Following UK practices, the EU could also impose maximum shares of risk based fibers in other Member States with SFM certificates when the compliance of woody biomass for energy is insufficiently in agreement with EU's sustainability goals.

C Long term future situation. Currently, risk based assessments are preferred as the costs for such a program are less expensive than the implementation of one in which all forests are certified (FM fibers). We think that in the long term, a considerably larger forest area can be certified, only when more financial means are available and the certification of small private forest areas is facilitated via group certification or otherwise. If so, the risk based assessments and also an extra cross-reference check in case of individual mass balances (situation A), would become less important.

5.2. Adaptation of Forest Legislation and Voluntary Forest Certification to Future Needs

In the previous Sections, we have sketched various sustainability concerns in the EU-relevant woody biomass sourcing regions of North America, mainly based on current certification practices. There are also concerns about the foreseen growth of biomass fibers from certified FM source regions. Only a few private forest areas in the Southeast US, a major exporting region of pellets to Europe, are certified [40]. The large number of small to medium private forest owners represent some of the bottlenecks for non-certified biomass areas, one of the feedstock sources for pellet manufacturers [94]. Nutrient and complete tree biomass removal, beyond traditional harvest of stems only, should be guided by additional (group) certification, BMPs or BHGs, in order to ensure long-term soil productivity [14,110]. A detailed inventory for British Columbia (BC), in Canada, another major biomass supplier, concluded that new forest practices for the recovery of energy wood were sufficiently covered in the SFM requirements by voluntary certification schemes. However, any extra intensification of removals raises concerns about nutrient depletion, especially when whole tree harvesting systems are involved. Modifications are required via adapted forest laws or SFM certification schemes, for example, in the case of excessive soil disturbance resulting from mountain pine beetle (MPB) salvage harvesting [26].

Another biomass supply region of interest for the EU is Northeast Europe. An impact analysis for Northeast European boreal forests concluded that (more) intensive harvesting practices for forest biomass (removal of slash and roots) for energy are not covered by current SFM standards [8]. Belarus intends to increase renewable energy via domestic forest resources, such as the use of high quality logs as wood fuel [83]. This is conflicting with the cascading principle, which is not adequately covered by SFM requirements (Table 3). The quality of Latvian forest management is under discussion as it increasingly supplies woody biomass to the EU's energy sector [111]. The extra harvesting activities are reported to have resulted in an increase of clear cutting areas, deforestation, and even in the loss of one SFM certificate [112]. The new practices for harvesting wood for energy need to be evaluated.

5.3. Forest Carbon and GHG Accounting Approach

The carbon accounting of woody biomass removals is not appropriately addressed, both on a global (national forest reports) and also at FMU certification level. A pressing problem is the emissions from forest biomass harvesting, as not every country has accounting obligations in the current Kyoto Protocol (KP) or intentions to do so in future. Neither the US nor Canada have signed such a protocol, leaving the risk [22] that GHG emissions from wood harvesting are not appropriately accounted for, while any GHG savings may be claimed by other countries like the EU-28, with obligations. The question is how to reach national goals and how to set the incentives for further participation. A good example is the voluntary reporting of countries around the world to the secretariat of the UNFCCC [113] by means of National Communications, in which carbon sequestration and emissions from forests are successfully recorded, as well as from other land use and land use changes.

Safeguards for carbon rich wetlands are insufficiently covered under the current FM schemes. Alternative best practices for compliance at the FMU level can be found under the KP umbrella. For the period 2008–2012, a total of 9573 projects have been set up for compensation of GHG emissions of the KP countries. The afforestation/reforestation (A/R) part consisted of 73 projects, mostly in tropical

countries [114]. The A/R rules were too complex and restrictive to apply. Meanwhile, more flexible forest schemes have been set up [115]. WWF's international Gold Standard [102] may be useful for complying with land use change topics: it has specific criteria to avoid leakage. Leakage is emissions that occur due to a shift of activities elsewhere, such as firewood collection, farming, and livestock. The WWF GS has stringent restrictions for the establishment of new forests (Appendix D1), but also for other land uses, where carbon stocks are affected. Those restrictions can help to address unwanted conversion of forests to agricultural lands, although this is an insignificant practice in North America. Note that this practice is quite relevant for other regions, for example where peatland forests are converted into forest plantations or other plantations.

With regards to GHG life cycle, post-consumer wood waste has a special status. It is exempted from most obligations. Only its origin should be documented through track and trace [33] and a GHG calculation should start from the waste collection point. Note that industrial wood residues are treated in the same way as virgin fibers that are directly sourced from the forest. However, the GHG calculation for industrial wood residues should start at sawmills or other places where the residues are produced.

6. Conclusions and Recommendations

Our objectives in this paper were (i) to provide an inventory of developments of sustainable biomass production schemes, following recent EU legislation (both formalized and under development), and (ii) to benchmark the coverage of this legislation, when wood product certificates for sustainable forest management (SFM) are used as proof of the related legislative requirements. The three main areas of legislation studied were the EU Timber Regulation for legal harvesting, the EU's 2010 recommendations for sustainable woody biomass sourcing for energy and the EU's Waste Directive for wood cascading. We studied SFM in North America, which is a major biomass supplier to the EU-28.

The basic EU legislation is the Timber Regulation to prevent illegal harvesting, which started in 2013 [6]. The EU has made recommendations for further sustainability criteria for solid biomass in a Communication [9]. The responsibility for checking compliance with legality and sustainable sourcing requirements for solid biomass lies with the EU Member States. Our comparison was triggered by the UK's legislation for solid biomass for renewable energy goals, which allows for legal and sustainable sourcing via existing frameworks for SFM certification. SFM certification consists of requirements for legal sourcing, forest management plans with long term harvesting goals, *etc.*

The question was to what extent are widespread SFM product certificates in the US and Canada able to prove legal and sustainable wood sourcing for energy to the EU-28? That is a pressing question, as North American forests are only partially certified for SFM (Table 2). Based on our benchmark results (Table 3) and the following Discussion Section 5, two major outcomes are relevant: (1) FM audits *versus* risk based assessments and (2) one overarching mass balance.

Our benchmark results show that forest management (FM) audits by FSC and PEFC international are the most suitable certification systems to cover the EU topics for legal and sustainable sourcing. CSA has only limited coverage due to the undefined status of the (draft) indicators used for a forest audit. All FM systems have a fairly limited coverage to prevent harvesting in forest areas with high carbon stock, apart from any independently introduced GHG calculation tools. In particular, the protection of carbon-rich areas, such as wetland forests and peat land-areas, is inadequately covered. WWF's Gold

Standard (GS) for new forest plantations and other land uses can help to address unwanted conversion of high carbon stock forest areas into forest plantations or other types of land uses with reduced carbon stocks. Where the forest management certified fibers of FSC and PEFC both show sufficient coverage for most sustainability topics, the respective complementary risk based fibers show considerable lower coverage. The possibility of using complementary evidence by specific risk assessments, FSC (Controlled Wood), PEFC (Due Diligence), or SFI (Fiber Sourcing), shows a serious weakness in fulfilling requirements II.A through II.F (Table 3). While the EUTR [7] is sufficiently covered by the FSC and PEFC modules, the 2010 Communications [9] are insufficiently covered. Weaknesses are found regarding logging restrictions in carbon-rich areas, maintenance of carbon stocks in managed forests, and possible excessive recovery of woody biomass after salvage logging. Further alignment on definitions of no-go areas will certainly contribute to legal and sustainable sourcing. In particular, SFI-FS shows an evident risk for products with non-sustainable fibers. This is due to less detailed track and tracing, which ends up at state level (instead of at the FMU level) and the possible occurrence of high risk fibers from outside North America. Finally, none of the selected SFM frameworks have prescribed any cascading principles for wood-waste material, resulting in an insufficient coverage of the EU's Waste Directive.

Full compliance with the EU's (draft) legislation will remain insufficient for mixed fibers, when different private labels exist next to each other and an overarching mass balance is lacking. When different actors unintentionally claim the same part of sustainable fiber input and output via separate checks without any cross-reference, there is no safeguard to prevent the remaining shares of abundant risk based fibers or non-approved fibers from flowing into the EU-market. Following the latest UK developments, the volume of risk based fibers, under the umbrella of FSC-CW, PEFC-DD, SFI-FS, will be limited to 30%. This is common practice for the labeling of FSC Mix 70% [71] and PEFC Certified [109] products, which must contain a minimum of 70% FM certified fibers. In addition, any mix in the biomass supply chain consisting of fibers from non-approved frameworks will now result in a total volume of non-certifiable biomass for the UK market, unless those fibers can comply with prescribed minimum (Evidence B) criteria.

In general, we recommend further harmonization of legal harvesting, sustainable sourcing and cascaded use requirements for woody biomass for energy with the current requirements of voluntary SFM certification schemes. We would like to propose the following technical topics for further consideration and elaboration:

- **Mass balance**. In the case of different private sustainability schemes, there is a risk that abundant shares of risk based fibers or remaining non-approved fibers will unintentionally flow into the EU market. We think it is crucial to have a cross-reference procedure in place to reach 100% compliance with the EU's (draft) legislation for legal harvesting and sustainable sourcing. We suggest one overarching mass balance between certification bodies per individual pellet plant, storage unit, or per aggregated group of plants (juridical entity) to verify the certification status of fibers for the EU energy markets. The completion of the SBP by EU's energy sector may help to address this topic.
- **Ceiling risk based fibers.** Currently, there are not enough FM certified fibers, while at the same time the EUTR and the US Lacey Act ask for compliance with their legal harvesting requirements. Risk based fibers from less stringent risk assessments can comply with these basic requirements.

However, from the perspective of more stringent sustainable sourcing, a limited use (ceiling) of risk-based biomass is preferred. It is recommended to have a debate on the EU level, to which extent the use of risk based fibers should be allowed and for which period, combined with the current state-of-the-art certification and the short term availability of the preferred, certified FM fibers. For example, the UK has selected a 30% ceiling for the use of risk based wood chips, wood pellets *etc.* by the UK energy plants, starting from 2015. All kinds of certified fibers will be evaluated via mass balances per actor in the supply chain; a remaining share of non-approved fibers is not allowed.

- **Mutual recognition.** FSC-CW products exclude the fibers from PEFC certified products, largely due to differences in the risk based fibers [39]. The compatibility of SFM certificates can be improved, when a mutually recognized assurance system is introduced. As a spin off, full mixing of FSC and PEFC fiber flows results in one uniform mass balance check by the forest and energy sector.
- **Group certification**. For individual forest owners, it is costly to reach FM certification for relatively small forest areas, which practically limits the intake of FM certified fiber supplies. The EU promise to facilitate certification of small forest holdings (Section 3.2) is also of interest for owners supplying biomass for energy, for example in Latvia and Portugal, where few smallholders are now certified.
- **Track and tracing**. Further investigation is needed to verify whether the North American upstream supply monitoring of risk based fibers by SFI-FS back to the state level is appropriate in comparison with the EU's prescribed approach to track and trace risk based fibers back to a detailed FMU level.
- **Vulnerable forest areas**. Further consensus amongst stakeholders in the EU and on a broader international level is needed on definitions of primary forests and high carbon stock areas. In general, current SFM certification schemes hardly cover the protection of carbon rich forests from possible unstainable harvesting practices. Private certification initiatives for wood product and biomass sourcing may extend their schemes with criteria for "leakage" (external GHG effects), as applicable for forest projects in WWF's GS [102]. This helps to address the vulnerable areas in or nearby FMU's.
- **Preliminary restrictions.** In the meantime, vulnerable high biodiversity forest areas should be excluded from biomass sourcing, unless evidence is provided that harvesting is not harmful. Together with exclusion of vulnerable areas, site-specific measures and obligatory indicators should be developed for the newest harvesting practices (e.g. slash recovery techniques in Scandinavia) and also exceptional tree removals after a natural hazard (e.g. salvage logging in North America).
- **Carbon accounting.** It is desirable that countries implement a full carbon accounting system that covers forest carbon pools and their stock changes (flows) in time and space. The UNFCCC umbrella for national forest carbon reporting [116] is a good example of how to complete carbon accounting at national levels, and a possible solution to deal with all types of carbon impacts in time. If applied by all wood producing and trading countries around the world, sustainable carbon stocks in managed forests can be sufficiently monitored via the national GHG reports. As a best practice example, the international methods of immediate GHG emissions from harvesting of forest biomass for energy and of delayed GHG emissions for HWP can be implemented on a country level [84]. Any other method of forest biomass harvesting (e.g. 'carbon debt' in time, depending on forest stand type, *etc.*) needs further guidance and should *a priori* not lead to complex bookkeeping methods. Although the intentions were to appropriately account for carbon in time and the right place, past experience with

carbon accounting for afforestation and reforestation (AR projects) under the Kyoto Protocol has shown that the issue of temporary forest carbon credits was made rather complex.

- **EU Waste Directive**. The recycling of waste fibers into other products is prioritized in the EU Waste Directive (cascading), when those processes have no adverse environmental or human health impacts. Recycling of waste wood in pellets is not yet practiced, due to unclear rules in the EU Waste Directive about overseas shipping (Section 3.3). Ideally, the trade of wood pellets from clean wood waste should be facilitated with less administrative barriers for the import by the EU, in order to have this new option seriously accounted for as a future resource for energy.

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Author Contributions

Richard Sikkema is the lead author and conducted all the benchmark analyses in this study. Gerben Stegeman provided the latest information for the major SFM frameworks of FSC and PEFC, next to his assistance with the EUTR implications. Martin Junginger and Andre Faaij are the PhD supervisors of Richard Sikkema, contributed to the methodological design and provided actual information on biomass certification and markets. Jinke van Dam assisted with the benchmark analysis, from the perspective of the EU Waste Directive and EU's 2010 Communications. English style and structure of the article were improved by David Durrant.

Conflict of Interest

The authors declare no conflict of interests.

List of Abbreviations

ATFS: American Tree Farm System
BC: British Columbia
BHG: Biomass Harvesting Guidelines
BMP: Best Management Practices
CB: Certifying Body (as officially accredited by SFM frameworks)
CITES: Convention on International Trade in Endangered Species of wild fauna and flora
COC: Chain of custody (terminology used by certifiers for downstream wood supplies)

CPET: Central Point of Expertise on Timber procurement
CSA: Canadian standards association (in our benchmark related to forest management standards)
CU: Control Union Certifications (Certifications Body)
DDS: due diligence system (terminology for framework set up for compliance with EUTR)
EC: European Commission
EUTR: European Union Timber Regulation (2010/995/EC)
EU-28: Member States of the European Union since January 2013, when Croatia joined the EU.
FM: forest management (used for sustainability standards related to the certifying forest areas)
FMU: forest management unit, more or less equal to DFA defined forest area
FSC: FM Forest Stewardship Council—forest management
FSC: CW FSC: Controlled wood (certificate related to fibers from non-certified forest areas)
GEC: Gross Energy Consumption
GHG: Greenhouse Gas
GGL: Green Gold Label (standard set up by the energy sector for sustainable biomass sourcing)
HCV: high conservation area
iLUC: indirect land use change
KP: Kyoto Protocol
MO: Monitoring Organisation (on behalf of the EUTR)
MPB: mountain pine beetle
NGO: Non—governmental Organisation
PEFC: FM Programme for the Endorsement of Forest Certification (see also FM)
PEFC: DD Due Diligence part of PEFC standard, related to fibers from non-certified forest areas)
RED: Renewable Energy Directive (2009/28/EC)
SBP: Sustainable Biomass Partnership (formerly Initiative Wood Pellet Buyers or IWPB)
SFI: FM Sustainable Forestry Initiative (related to Forest Management)
SFI: FS Idem, but related to the Fiber Sourcing part only
SFM: Sustainable forest management (overall programme for FM and Chain of custody criteria)
SGS: Société Générale de Surveillance (Certification Body)
UK: United Kingdom
UNFCCC: United Nations Framework on Climate Change Convention
US: United States
VPA: Voluntary Partnership Agreement (related to Forest Law Enforcement Governance and Trade)

Appendix A. Overview of Potential Wood Flows for Bioenergy in the EU-28 [117]

The EU's annual harvest in 2010 was about 424 million m^3, divided into 335 million m^3 for industrial roundwood (sawmills, panels, and wood pulp) and 88 million m^3 for fuelwood. With a net import of about 15 million m^3 roundwood, the total consumption of roundwood in the EU is about 450 million m^3 [21]. This consumption is equal to 180 million tonnes of industrial roundwood and 45 million tonnes of fuelwood. The total roundwood consumption of EU-28 plus all other European countries under IPCC 2030 projections for low and high energy use scenarios is expected [118] to increase from 645 million m^3 in 2006 to 663 million m^3 (low energy use) and up to 859 million m^3 for high energy use in 2030. The sub shares of industrial roundwood remain more or less stable, while EU's demand for energy wood is expected to increase from 145 million m^3 in 2006 to about 155 million m^3 and 360 million m^3 respectively in 2030, an increase of 10 to 200 million m^3 of wood (about 5 to 120 million dry tonnes). The current share of virgin wood (from forest and forest industries) and wood waste in EU's gross energy consumption (GEC) in 2011 is 3.4 EJ, *i.e.*, 4.8% of total GEC [119]. This is equal to about 195 million tonnes of dry wood with an energy value 17.5 GJ per tonne.

The UNECE Forest Section [120] compiled a detailed wood balance for the EU in 2010 (Table A1). Five main sectors are considered, of which two are relevant for bioenergy: residential heating (Sector 1) and industrial heating and power (Sector 2). Energy needs of the forest industries are included in Sector 2, consisting of woody biomass for heat (drying processes) and electricity production. The others are producers of pulp (Sector 3), panelboard (Sector 4) and lumber (Sector 5).

- **Residential heating**. The majority of EU's woody biomass consumption is related to households, *i.e.*, residential heating: about 91 million dry tonnes. About 77% of this is supplied via fuel wood (low quality logs) from the forests. The remaining feedstock is supplied by wood pellets and post-consumer wood waste [120].
- **Industrial heating and power**. According to Mantau [120], the energy sector consumed about 44 dry million tonnes of woody biomass for power and heating. The feedstock consisted of about 49% of low quality pulpwood or fuelwood, 35% of wood chips (including other residues like bark and sawdust), 13% of post-consumer wood waste and 3% of wood pellets. EU's forest industries consumed about 14 million dry tonnes of low quality wood and 32 million tonnes of pulp waste for their internal energy needs.
- **Pulp production**. According to CEPI's division for the pulp and paper sector in the EU-28 plus Norway [121], the pulp sector used 26% wood chips and 74% pulpwood for the production of pulp in 2010. This pulp is used for paper production in a next stage, together with waste paper.
- **Panel boards**. According to a detailed division by the European Panel board Federation (EPF) [122], OSB mills (with about 3 million tonnes of woody feedstock), MDF plants (9.5 million tonnes) and particle boards manufacturers (19.5 million tonnes) use on average 40% pulpwood, 43% industrial residues (chips and others) and 17% post-consumer wood waste in 2009. This division is similar to that compiled for 2010 [120].
- **Lumber, veneer and plywood**. The sawmills use 100% high quality trees (sawlogs), which are not interfering with bioenergy markets due to current market conditions resulting in high prices for the sawlogs [32]. The same is valid for veneer and plywood [120].

Table A1. The division of different woody feedstock use for energy (in % of total) per sector [120–122]. Forest sector's internal use is covered in Sector 2. Conversion of energy use categories about 0.54 tonne per m^3 feedstock [120], and of pulp industry about 0.475 tonne per m^3 [84].

		Wood pellets	Chips		Other residual wood	Low quality round wood **		Total input of feedstock
			Coniferous	Non Coniferous *)	(particles, sawdust and post consumer wood waste)	Fuelwood	Pulpwood	
1	**Energy use small scale 2010 [120]**	17%		0%	6%	77%	0%	**91 million tonne**
2	**Energy use large and medium scale 2010 [120]**		(chips including other industrial residues)		(mainly post-consumer wood waste)			**90 million tonne ***
	- CHP's etc energy sector	3%	35%		13%	49%		43.9 million tonne
	- CHP's forest industries	0%	0%		4%	96%		13.9 million tonne
	- pulp waste (black liquor)	No trade; only internal use within pulp- and paper industries						32.3 million tonne
3	**Pulp industry 2012 [121]**	0%	23%	1%	0%	0%	76%	**70 million tonne **)**
4	**Panelboard industry 2009 [122]**							**32 million tonne**
	- OSB	0%	0%	0%	0%	0%	100%	3 million tonne
	- MDF	0%	53%		0%	0%	47%	9.5 million tonne
	- particleboard	0%	48%, mainly other industrial residues		24% post-consumer wood waste	0%	28%	19.5 million tonne
5	**Sawmills 2010 [120]**							**Feedstock not applicable for energy**
	- sawnwood	0%	0%	0%	0%	0%	0%	Only high quality sawlogs
	- veneer and plywood	0%	0%	0%	0%	0%	0%	Only high quality sawlogs

* Conversion of all categories, except pulp, is estimated at about 0.54 tonne per m^3; ** CEPI data is related to pulp production only and includes data of Norway; Conversion for pulp: 0.475 tonne per m^3.

Appendix B. Checklist for Legal and Sustainable Sourcing, in Case of Evidence B

The CPET approach is set up for the sustainability of wood and paper products in the UK [33,123], but is also valid for production, trade and consumption of sustainable biomass for energy under the ROC scheme in the UK [32,64]. Next to common evidence of sustainability via SFM schemes ("Evidence A"), the CPET approach allows for other evidence ("Evidence B") via, for example, risk based assessments. The CPET holds three types of checklists (all under review) for this other evidence. It consists of all kinds of information, which can be systematically and consistently assessed by procurement staff:

1 Supply chain information
2 Forest source information for legality
3 Forest source information for sustainability

1. Supply chain information (chain of custody)

The main elements to be provided are:

- Supply chain description
- Controls for preventing mixing or substitution.
- Mechanisms for verification.
- Which kind of evidence is available or provided.

2. Forest source information for legality (legal sourcing)

The main elements provided are:

- The forest owner/manager holds legal use rights to the forest.
- There is compliance by both the forest management organization and any contractors with local and national laws including those relevant to forest management (FM), environment, labor and welfare, health and safety and other parties' tenure and use rights.
- All relevant royalties and taxes are paid.
- Whether there is compliance with the requirements of CITES.

3. Forest source information for sustainability (sustainable sourcing)

The main elements provided are:

- There must be a definition of sustainability based on a widely accepted set of international principles and criteria defining sustainable or responsible forest management (FM) at the forest management unit level (FMU).
- The process of defining "sustainable" must seek to ensure balanced representation and input from the economic, environmental and social interest categories. (i) No single interest can dominate the process; (ii) No decision can be made in the absence of agreement from the majority of an interest category.

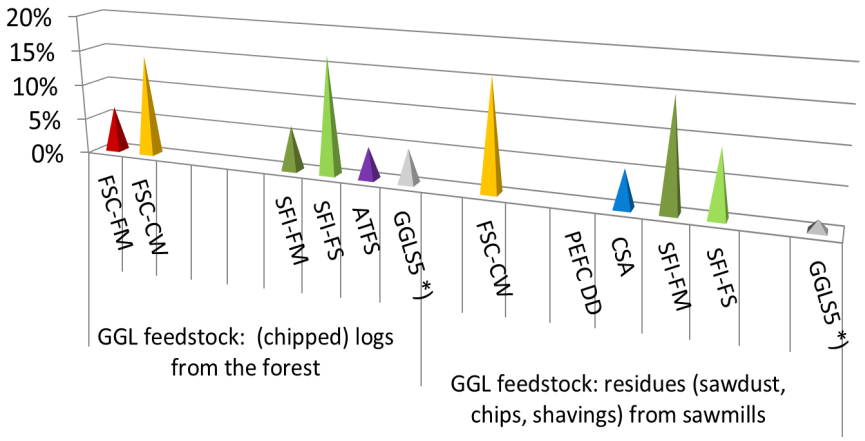
In addition, the management of the forest must:

- Ensure that harm to ecosystems is minimized. In order to achieve this there must be (i) appropriate assessment of impacts and planning to minimize impacts; (ii) protection of soil, water and biodiversity; (iii) controlled and appropriate use of chemicals and use of integrated pest management wherever possible; (iv) proper disposal of wastes to minimize any negative impacts.
- Seek to ensure that productivity of the forest is maintained. In order to achieve this the definition of sustainable must include requirements for: (i) Management planning and implementation of management activities to avoid significant negative impacts on forest productivity; (ii) Monitoring which is adequate to check compliance with all requirements, together with review and feedback into planning; (iii) Operations and operational procedures which minimize impacts on the range of forest resources and services; (iv) Adequate training of all personnel, both employees and contractors; (v) Harvest levels that do not exceed the long-term production capacity of the forest, based on adequate inventory and growth and yield data.
- Seek to ensure that forest ecosystem health and vitality is maintained. In order to achieve this the definition of sustainable must include requirements for: (i) Management planning which aims to maintain or increase the health and vitality of forest ecosystems; (ii) Management of natural processes, fires, pests and diseases; (iii) Adequate protection of the forest from unauthorized activities such as illegal logging, mining and encroachment.
- Seek to ensure that biodiversity is maintained. To achieve this, the definition of sustainable must include requirements for: (i) Implementation of safeguards to protect rare, threatened and endangered species; (ii) The conservation/set-aside of key ecosystems or habitats in their natural state; (iii) The protection of features and species of outstanding or exceptional value.
- Legal, customary and traditional tenure and use of rights of indigenous peoples and local communities related to the forest are identified, documented and respected.
- Management of the forest must ensure that appropriate mechanisms are in place for resolving grievances and disputes including those relating to tenure and use rights, to forest management practices and to work conditions.
- Ensure that the basic labor rights of forest workers are safeguarded. In order to do this the standard must include requirements concerning the following: (i) freedom of association and the effective recognition of the right to collective bargaining; (ii) the elimination of all forms of compulsory or forced labor; (iii) the effective abolition of child labor; (iv) the elimination of discrimination in respect of employment and occupation.
- Ensure that appropriate safeguards are put in place to protect the health and safety of forest workers.

Appendix C. One Example of Combining SFM Certification and Sustainable Sourcing

By the end of 2012, the GGL program had certified about 3 million tonnes of pellets per annum, equal to more than 6 million tonnes of (wet) feedstock [94]. These (pre-certified) feedstock volumes were mostly sourced from the forests in the US, Canada, Russia, Latvia and Portugal. For comparison, the EU imported 8.3 million tonnes of pellets in 2012 (Table 1), consisting of both industrial pellets and non-industrial pellets. Figure A1 shows the sourcing of pellets under the GGL umbrella. GGL allows for SFM certification prior to the certification of wood pellet plants by means of a mass balance book keeping system. As illustrated, FSC, SFI, ATFS and CSA all have a major input share (feedstock) in GGL certified wood fibers. SFI is actually split into two systems: one for forest management and the other for downstream procurement (controlled sourcing). FSC also consists of two systems: forest management and controlled wood (CW). FSC-CW is most applicable for the GGL fiber sourcing (both logs and residues), followed by SFI-FS and SFI-FM. ATFS, CSA, FSC-FM and GGLS5 have a lower share. GGLS5 is an internal standard of the GGL program, derived from FSC and PEFC frameworks and the sustainability criteria from the RED [1]. GGLS5 is not developed to replace existing standards. It is made to enable participating parties and stakeholders to perform a quick-scan assessment on sound forest management practices prior to wood pellet and other biomass production. Within a period of 4 years, further certification should be initiated under the GGL approved certification schemes of FSC or PEFC [66]. Finally, although recycled fibers (like waste wood chips) are used for energy in Europe, they are not checked by the GGL sustainability program and their volumes are thus left out of the Figure A1.

Figure A1. Share of SFM certificates (in % of tonnes wet feedstock **) in the solid biomass certification framework of the Green Gold Label in 2012 [94].



* GGLS5 = internal GGL standard for FM [66], mostly feedstock sourced from small Portuguese forest plantations; ** 1 tonne of pellets is equal to about 2 tonnes of wet feedstock with a moisture content between 45% and 55%, but losses excluded.

Appendix D. Inventory of Mutual Compliance for Legal and Sustainable Wood Sourcing

D1. Benchmark of FM Frameworks (FM Fibers)

The FM systems involved in our benchmark show sufficient compliance (√) with the EU Timber Regulation. Both FSC and all selected PEFC endorsed frameworks have criteria to prevent possible illegal harvesting practices:

- √ FSC criterion 1.4. The forest manager shall develop and implement measures—to systematically protect the Management Unit from unauthorized or illegal resource use, settlement *etc.*
- √ PEFC COC (applicable for all traded products under PEFC, CSA, SFI or ATFS scope). Criterion 5.6.2. Timber known or reasonably suspected as coming from illegal sources ("controversial sources") shall not be processed and shall not be traded and/or shall not be placed on the market.

A. GHG Calculation of forest Operations

The FM frameworks of FSC, PEFC and ATFS do not have criteria for (maximum) GHG emissions from forest operations. Exceptions are the CSA and SFI programs with a partial, limited coverage (±):

- ± CSA indicator 6.3.4.4 refers to Forest conditions and management activities that contribute to the health of global ecological cycles. Machine operations generate emissions of carbon dioxide and other compounds that contribute to climate change. Thus, the lower that forest managers can make the emissions during forest operations, the better for the environment. Therefore, Carbon emissions of fossil fuels in forest operations are included as a discussion item via an informative annex [124]. As such, this indicator is still subject to further discussion within CSA (see Section 4).
- ± SFI shall provide financial support for forest research to improve SFM (measure 15.1). The research shall include some of the following indicators: I. Forest operations efficiencies and economics combined with indicators J. energy efficiency and K. Life cycle assessment. As not all issues need to be included, we regard SFI to have a rather limited coverage.

Note that the PEFC Annual meeting in 2012 discussed the option for inclusion of CO_2 emission criteria [125], but so far, this inclusion is not officially proposed by the Board of PEFC International.

B. Protection of High Biodiversity Areas, Including Primary Forest Areas

High biodiversity areas are designated by law or can be identified by international agreements or environmental NGO's such as IUCN and WWF. The international Convention of Biological Diversity (CBD) has recognized protected areas as cornerstones of biodiversity conservation and adopted 10% of each of the world's forest types by 2008. IUCN has developed 6 categories, of which 4 are protected areas with restrictions for harvesting, and 2 designated for multiple use of forests. WWF has ranked the most biologically outstanding ecosystems through the establishment of more than 200 global eco-regions. In relation to the protection of significant biodiversity areas a broader concept, 6 types of high conservation value (HCV) forests were first defined by FSC and later also used by others [12]. Note that IUCN and WWF areas do not always have a legal designation, and as such are not eligible with the RED intentions to have legally restricted no-go areas.

Primary forests are defined by the RED [1] as follows: Forests of native species where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. This is actually a standard FAO definition, and as such applied by PEFC International [97]. However, primary forest is not used as a category in forest and land use inventories in Canada. Those areas that correspond to the primary forest definition are either conserved in protected areas (unmanaged forests) or are part of the commercial forest land base (managed forests) [126].

Although both the RED and FSC cover principles for biodiversity and HCV areas, the approach for selecting and recognizing them is different. Whereas RED follows a factual definition, FSC follows the more extensive HCV approach where areas are defined in a process of consultation and which includes social and cultural forest values. Consequently, the destination of HCV areas and level of protection can differ between FSC and RED, although both recognize its importance.

The coverage is presumed to be sufficient in the following frameworks:

√ FSC Principle 9 The maintenance of HCV areas, requires that the forest management shall have the following elements:

- Assess and record the presence and status of HCV areas in the FMU (Criterion 9.1);
- Develop and implement effective strategies to maintain or enhance the identified HCV's (Criteria 9.2 and 9.3) and
- Demonstrate that periodic monitoring is carried out to assess changes in the status of HCV and adapt its management strategies to ensure their effective protection (Criterion 9.4).

FSC's BC standard classifies old growth areas to be maintained in the *range of natural variability* (RONV) [127]. This is the dynamic change in natural systems in the last 2000 years prior to the influence of European settlers. FSC-BC includes First Nations' prehistoric management systems (e.g., burning) as an integral part of the RONV [96].

√ PEFC International main criterion 4 is dealing with The maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems. Forest management planning within PEFC shall consist of the following steps:

- Aim to maintain, conserve and enhance biodiversity on ecosystem, species and genetic levels and, where appropriate, diversity at landscape level (Criterion 5.4.1) and
- together with inventory and mapping of forest resources, FM planning shall identify, protect, and/or conserve ecologically important forest areas containing significant concentrations of 4 detailed types of biodiversity areas (Criterion 5.4.2). PEFC notes that "This does not necessarily exclude forest management activities that do not damage biodiversity values of those biotopes". Thus, harvesting of wood is allowed in these areas under certain conditions.

√ ATFS has a commitment (Indicator 1.1.2) that management plans must address, amongst others, the following resource elements: threatened and endangered species and HCV forests. In addition, FM activities should maintain or enhance HCV forests (performance measure 5.4). ATFS states for this commitment: Informal assessment of HCV forest occurrence through consultation with experts or review of available and accessible information is appropriate, due to the small scale and low intensity of family forest operations [101]. ATFS has another Indicator (7.1.1) that Forest

owners must make a reasonable effort to locate and protect special sites (like unique ecological communities) appropriate for the size of the forest and the scale and intensity of FM activities.

√ The SFI program has 4 main objectives related to biological conservation. Objective 1 (FM planning) should include a review of, amongst others, pilot projects and programs to promote biological diversity conservation. Objective 2: Ensure long term conservation of forest resources through soil conservation and other measures. Objective 4: The SFI participants shall support or participate in plans or programs for the conservation of old growth forests in the region of ownership (e.g., Performance Measure 4.2 states: participants shall provide information to the landowners for wildlife and biodiversity, including forests with exceptional conservation value). Objective 11 is related to Conservation of Biological Diversity, Biodiversity Hotspots and High-Biodiversity Wilderness Areas (e.g., Performance Measure 11.1 states Program participants of SFI certified sources shall include efforts to promote conservation of biological biodiversity).

The Canadian forest legislation prescribes that old growth management areas have to be identified in forest stewardship (Section 2). Old growth forests are actually addressed in two different ways: either they are included in regulations for protected areas and biodiversity, or special management of old-growth forests and forests with special values is required [127]. In case of CSA, we still remain unsure how site by site protection is guaranteed for high biodiversity areas in BC and other regions.

± CSA participants will have to identify sites of special biological significance within the defined forest area (DFA, similar to FMU) and implement strategies appropriate to their long term maintenance (Element 4.1). However, CSA has earmarked old growth as a discussion item, when it refers to the conservation of old growth forest attributes (e.g., dead trees). We regard this as partially covered, as long as it is not included as a core indicator for the audit process (Section 4).

C. Safeguard of High Carbon Stock Forests (Protected Forest Areas)

√ FSC has included this topic in the explanatory notes and rationales; as such it has an informative rather than a prescriptive status. Criterion 9.1 of the notes states that High carbon forests and intact forest landscapes can be classified as high conservation value (HCV) areas. However, to date there is no consensus on how to incorporate this in the FSC principles and criteria.

√ PEFC International refers to Forest management practices that shall minimize direct or indirect damage to soil (Criterion 5.1.9) and that Special care shall be given to silvicultural operations on sensitive soils and erosion prone areas. Inappropriate techniques such as deep soil tillage and use of unsuitable machinery shall be avoided in such areas (Criterion 5.5.3). Nevertheless, we regard this topic as partially covered, as the protection of high carbon stocks is not explicitly required.

√ The Gold Standard reflects the protection of forests with high carbon stocks: the project area shall not be on ground with permafrost, not be on wetlands, soil disturbance shall be lower than 10% of the total project area and organic soils shall not be drained (Criterion 5.1 Applicability). In addition, the emissions of forest operations (site preparation; fertilization) can be subject to a GS requirement: Criterion 5.4. Other emissions.

Within the other frameworks, this topic is partly (SFI) to insufficiently (CSA and ATFS) covered. The criteria and indicators included are more suitable for compliance with monitoring of carbon stocks in managed forest, rather than the protection high carbon stocked areas like wetlands and peat land.

± SFI forest management has an explicit reference to carbon stocks. Indicator 1.1.1 prescribes *FM* plans to include a review of non-timber issues, amongst them carbon storage and bioenergy feedstock. In addition, performance Measure 3.2 prescribes The identification and protection of non -forested wetlands etc. After screening audit reports on this topic [128], it is not clear if high carbon forest areas are included in the forest audit.

- Also CSA has covered the topic of carbon via element 4.1: Maintain the processes that take carbon from the atmosphere and store it in forest ecosystems. Core indicators are net carbon uptake and reforestation success. It is not made clear in the audit reports (public summaries) if and how any possible high carbon storage forest areas are included for protection in the FM [129–133].
- Finally, ATFS has a commitment for practicing sustainable forestry, consisting of the Indicator 1.1.2, which suggests but does not require the plan to address carbon storage where present and relevant [134]. In addition, the FM plan has wetlands included as optional*:* If they are present and desired by the forest owner. Thus, protection of high carbon stocks is not obligatory for the ATFS check.

D. Sustainable Harvest rates and Carbon Stocks (managed Forests)

The possible removal of full trees including foliage is an on-going forest practice in southeast US. During a field trip by the authors in Georgia [69], it was observed that the recovery and chipping of complete low quality trees took place side by side with the removal of high quality saw logs for industrial processing. This area was subject to the BMP of the state of Georgia [45]. For comparison: in Scandinavian certified forests, most foliage will remain on site (for the maintenance of the nutrient balance); slash will only recovered after a certain minimum period [8]. The removal of forest residues and its impact on forest soil in the US is sufficiently safeguarded via the respective SFM programs:

√ FSC participants should pay attention to the occurrence of live wildlife trees and snags and relative amounts of slash. More specifically, the regional (BC) standard states The detrimental soil disturbance should be limited to 7%–10% of the total forest management unit (Criterion 6.3.14).

√ PEFC Criterion 5.3.6 prescribes Harvesting levels of both wood and non-wood forest products shall not exceed a rate that can be sustained in the long term. Optimum use shall be made of the harvested forest products, with due regard to nutrient off-take. Note that the PEFC global criteria are an umbrella for other frameworks to cover this topic (more in detail). Consequently, the loss of nutrients in the forest, after the removal of woody biomass, is not covered by PEFC indicators.

√ The SFI program has a three-step approach: criterion 8.1 provides guidance on Management of harvest residues, taking Environmental factors like organic and nutrient value to future forests into consideration. Criterion 1.41 provides Guidance on ecological impacts of bioenergy feedstock removals. Performance measure 2.3 states that Post-harvest conditions conducive to maintaining site productivity (e.g., retained down woody debris). The SFI FM program prescribes

a maximum clear cut area of 50 ha, which may cover our concerns of possible carbon loss after large scale harvest (Section 3.4). Note that a 50 ha limit by itself is not a guarantee for carbon maintenance.

The PEFC endorsed CSA and ATFS programs have a relative low coverage for intensive harvesting, although both included the indicator "Carbon storage" (see topic C High carbon stocks).

± CSA explicitly includes the Level of soil disturbance (Criterion 3.1.1), together with the Level of downed woody debris (Criterion 3.1.2). However, both parameters are currently under discussion for future inclusion in CSA. It remains unclear whether they are included as a default value during the certification audit (Section 4). Note also that the informative annex (non-mandatory) to the CSA guidelines prescribes Forest managers to develop clear operational guidelines for the removal of biomass. The CSA program does not have a limit for the final felling area, leaving uncertainty about possible carbon losses after large scale felling (Section 3.4).

± Where present, relevant to the property, and consistent with landowner's objectives, the ATFS FM plan (Indicator 1.1.2) preparer may consider, describe and evaluate resource elements, amongst them biomass and carbon. Further, no limit for the clear cut area is indicated (similar to CSA before). We consider this item as partially covered, as it remains unsure whether and how intensive biomass harvesting and clear cut are guided and if any restrictions are applied.

E. Preventing Deforestation (Replanting and Natural Generation after Harvest)

Natural regeneration and replanting after harvesting is a common practice for most frameworks and consequently marked as sufficient for the following systems:

√ The FSC global standard requires forest regeneration, succession and natural (harvest) cycles for maintaining native species in the long term (Criterion 6.6) plus appropriate regeneration for the landscape values in that region. In BC, natural replanting should use local seedlings or seeds. BC's Criterion 6.1 states Forest conversion to plantations or non-forest land shall not occur, except in circumstances where conversion (a) entails a very limited portion of the FMU; does not occur on HCV Forest areas; will enable long term conservation benefits etc., across the FMU.

√ Under the PEFC International scheme (Criterion 5.1.11), Conversion of forests to other types of land use, including conversion of primary forests to forest plantations, shall not occur unless in justified circumstances where the conversion is in compliance with national laws; entails a small portion of forest type and does not have negative impacts on threatened forest ecosystems *etc.*

√ Within SFI forest management (Objective 2), Natural regeneration and planting should occur within a period of 5 years and 2 years respectively after harvesting has taken place. Monitoring is required to check the progress of regeneration, growth and drain (harvest).

CSA and ATFS have divergent specifications. We classified them as partially insufficient coverage.

± CSA has several clauses for preventing deforestation: Element 2.2 Conserve forest ecosystem productivity and productive capacity by maintaining ecosystem conditions that are capable of supporting naturally occurring species. Reforest promptly and use tree species ecologically suited

to the site. CSA Element 4.2 Forest land conversion should protect forest lands from deforestation or conversion to non-forests, where **ecologically appropriate**. Forest managers should address and monitor these elements via two core indicators "Additions and deletions to the forest area" and "Proportion of the calculated long-term sustainable harvest level that is actually harvested". The first indicator ("additions and deletions …") is a particular one. After consultation of some public summaries of audit reports [129–133], we conclude that the current defined forest area (DFA) is always indicated, but not the DFA of the previous auditing stage. This raises the concern whether the deforestation monitoring is applicable for the project level (certification stage) or whether it should be monitored at province or at country level (national reporting to the IPCC).

- ATFS. There is no specific prescription for this topic, in terms of timing. Only general preferences are stated: natural regeneration stocking assessment should be held and account for both coniferous and non-coniferous species. Based on the anecdotal evidence from a single audit for GGL's certification program [94], part of the sourced forest area in the southeast US was converted to agricultural purposes after the final cut in 2011. These forests were established by farmers since 1930 and harvested within 20 to 40 years. The larger landowners actively replanted the area, but the smaller ones relied on natural regeneration. Due to their low wood revenues, a small (insignificant) part of these forests is nowadays converted to agriculture [135].

F. Exceptional Removal of Salvage Trees

As a result of MPB outbreaks, harvesting in interior BC nowadays includes extensive salvage of standing trees for timber *etc.* When nothing is done, timber supplies will significantly decline, as the affected trees deteriorate within 15 years and can be considered as "not merchantable" [136].

√ FSC regional framework for BC has a Criterion 9.1.1 for natural disturbance regimes and a detailed checklist for the identification of (remnant) intact forest landscapes. In addition, the BC Criterion 6.1.2 states The manager collects inventory information appropriate for landscape level planning and for completion of a forest management plan (FMU level), including a natural disturbance regime. In its explanatory notes [95] to its global framework, FSC states The FM shall reduce potential negative impacts from natural hazards (Criterion 10.9). Pests, plant diseases, etc. can be minimized by clearance of fallen wood, standing dead wood and coarse woody debris, in line with best scientific and local knowledge. Further, the current regional BC standard (Criterion 5.6) requires that in any given year no more than 25% above the projected long-term harvest level shall be recovered unless there is a catastrophic event. Within one year, a 25% limit can be temporarily exceeded but the forest manager must ensure that a 5 year average does not exceed the sustainable long-term level (Annual Allowable Cut or AAC). Overall, FSC has this item sufficiently covered.

In an informal note [137], FSC International confirmed that the elevated rate of harvest in beetle-affected areas does conflict with regional Criterion 5.6. In its note, FSC left the option open to have existing restrictions altered somehow in the future and to ensure that any new BMP requirements could be carried out, including those for the natural disturbance regime.

√ PEFC Criterion 5.2.3 The monitoring and maintaining of health and vitality of forest ecosystems shall take into consideration the effects of naturally occurring fire, pests and other disturbances. In addition, PEFC Criterion 5.4.13 states that Standing and fallen dead wood and hollow trees shall be left in quantities and distribution necessary to safeguard biological biodiversity, taking into account the potential effect on the health and stability of forests and on surrounding ecosystems. We consider these statements as sufficient for the coverage of salvage logging.

Despite the fact that the MPB outbreak began over 15 years ago, three FM frameworks have not yet provided any publicly available documents about salvage logging in MPB-attacked BC forests [138]:

± CSA Criterion 6.3.2 Conserve forest ecosystem condition and productivity by maintaining health, vitality, and rates of biological production, includes a list of discussion items. For example, the public participation process shall include discussion about the proportion of naturally disturbed area that is not salvage harvested. We consider this item as partially covered, as a discussion item is a first step for further inclusion as a core indicator during the audit stage (Section 4).

➢ ATFS Indicator 1.1.1 states Management plan must be active, adaptive, and embody landowner's current objectives. However, the nature of adaptive management requires that the landowner is not bound to follow the management plan prescriptions when circumstances are influencing the property. Examples of such changes would include major damage from storms, fire, pest or disease outbreaks. For lacking any indicators, we consider this item as insufficient covered.

➢ SFI Program Participants shall manage so as to protect forests from damaging agents, such as environmentally or economically undesirable wildfire, pests, etc., to maintain and improve long-term forest health, productivity and economic viability (Performance Measure 2.4). It remains unclear how the forest is monitored after any exceptional circumstances (*i.e.,* natural disturbances) have occurred. Therefore, we regard this item as insufficiently covered.

D2. Benchmark of Risk Based Assessments (Risk Based Fibers)

In case of the EUTR, the issue of traceability of wood fibers is the most crucial topic for detecting any possible illegal harvesting practices. This is sufficiently covered (√) by FSC CW and PEFC DD, but insufficiently covered (×) by the SFI-FS program.

√ FSC. The main pillar of FSC controlled wood is the avoidance of illegally harvested wood trading.

√ PEFC DD is completely set up to comply with the EUTR (see also Section 3.1).

× SFI-FS. Generally, fibers within SFI-FS can only be traced back to an aggregated (state) level instead of the desirable level of a regional FMU (see below). We have earmarked this item as insufficient coverage, as state wide coverage can accidentally include a medium or a high risk area.

In a separate interpretation note [99], SFI has clarified the question whether monitoring systems can track fiber from its end use back to the harvest area. SFI program participants must establish systems that generate verifiable information for wood procurement from lands not owned or controlled by the participant. State-wide monitoring programs and other regional data may be sufficient with the SFI procurement program, if the participant can demonstrate that the data are (i) credible and independently verifiable and (ii) relevant to and reflective of the Participant's specific operations.

The complementary risk based frameworks mostly have an insufficient coverage of sustainability topics (Table 3), except for the topics (B) high biodiversity forests and (E) preventing deforestation.

A. GHG Forest Operations

- ➢ Similar to the FM benchmark (Appendix D1), the compliance with GHG calculation is insufficiently covered by FSC-CW and PEFC-DD and partially covered by SFI certification.

B. Protection of High Biodiversity Areas, Including Primary Forests

Actually, only in the case of protection of high biodiversity forests, the sustainability of remaining (non-certified) fibers is guaranteed for all frameworks, except for SFI-FS.

- √ FSC CW has a main function to prevent trading in wood harvested from forests with high conservation value (HCV) where they are threatened by management activities. Following the FSC harvest restriction to HCV forests, *intact forest landscapes* are explicitly included as a no-go area.
- ± PEFC DD does not allow harvesting from controversial sources. These include, amongst others, forestry operations and harvesting from protected forests with biodiversity conservation values and also the conversion of forest to other uses. PEFC DD includes a clause for the Due Diligence System (see Section 3.1), which prevents the conversion of forest to other vegetation type, including conversion of primary forests to forest plantations (Criterion 5.1.9) However, we regard this clause as partial coverage as wood harvest from primary forest areas is not restricted.

The SFI-FS program has limited criteria for wood procurement, excluding the Objectives 1 through 7 and including Objectives 8 onwards (see Section 2 for the applicable objectives).

- ± Remaining Objective 11 and its performance Measure 11.1 (Program participants of SFI certified sources shall include efforts to promote conservation of biological biodiversity) may be regarded as a first step to guarantee the protection of highly bio-diverse forests in North America. Remarkably, Objective 11 and its measures are not applicable for non-domestic fibers. This exception leaves a risk for fibers from unwanted sources outside North America and the possible mix with domestic fibers into one product. We regard this topic as insufficiently covered.

C. Safeguard of High Carbon Stock Forest Areas (Protected Forest Areas)

- × High carbon stocked forest areas are not covered by any of the alternative frameworks.

D. Sustainable Harvest Rates and Carbon Stocks (Managed Forests)

- ± The additional removal of slash and stumps has only one single safeguard left, when fibers switch from the SFI-FM to the SFI-FS program: Criterion 8.1: providing global guidance on the management of harvest residues. It takes environmental factors like organic and nutrient value to future forests into consideration. We regard this global guidance to partially cover this topic, as the monitoring of the level of nutrients (and others), both before and after harvesting, is not required.
- × This item is not covered at all by the FSC and PEFC complementary frameworks.

E. Preventing Deforestation (Regeneration and Replanting Practices)

This item is covered by both FSC CW and PEFC DD, via preventive measures for any conversion of permanent forest areas.

√ PEFC [72] states the organization shall operate a DDS (Criterion 5.1) to minimize the risk that the procured material originates from controversial sources, like converting forest to other vegetation type (including conversion of primary forests to forest plantations).

√ Criterion 6.1 is relevant for FSC CW [103,104]: No conversion of natural and semi-natural forests and other wooded ecosystems to plantations or non-forest uses take place.

Replanting or regeneration is not guaranteed by SFI-FS, thus this topic is insufficiently covered.

× In contrast to SFI FM, reforestation has only a voluntary status in SFI-FS. Program participants of SFI-FS shall supply regionally appropriate information or services to forest landowners describing the importance of reforestation and afforestation and providing related implementation guidance.

F. Exceptional Removal of Salvage Trees

× This item is not covered by any of the alternative options FSC CW, PEFC DD and SFI FS.

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