Feasibility of verifying sustainable forest management principles for secondary feedstock to produce wood pellets for co-generation of electricity in the Netherlands

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Feasibility of verifying sustainable forest management principles for secondary feedstock to produce wood pellets for co-generation of electricity in the Netherlands

Inge Stupak

(Department of Geosciences and Natural Resource Management, Faculty of Science, University of Copenhagen, Denmark)

C. Tattersall Smith

(Department of Geography & Planning, University of Toronto, Ontario, Canada)

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Executive Summary

The background for this research report is a current dispute in the Netherlands in connection with the implementation of the Dutch *Agreement on Energy for Sustainable Growth* and a 'Covenant' that has been agreed between the Dutch energy industry and NGOs. This dispute makes it relevant to assess the feasibility of verifying compliance with sustainable forest management (SFM) requirements for wood pellets that are made, in part or in whole, from secondary residue feedstocks, and whether lack of SFM requirements for secondary residues (including sawdust) will result in an increased pressure on forests.

In order to analyze the first issue, we defined four policy scenarios for which the technical, economic and cultural feasibilities were assessed. The analysis focused on forest owners, wood dealers and sawmills, as we considered the largest challenges to occur upstream from the pellet plant. The geographical focus was on supply chains from southeastern United States (SE US) and the Baltic countries, Estonia, Latvia and Lithuania, to the Netherlands. The four policy scenarios were defined as follows:

1. Secondary feedstock does not require documentation of compliance with any SFM standard.
2. Secondary feedstock requires documentation that it comes from forest with a verified low risk of non-compliance with standards for non-controversial sources ('controlled biomass').
3. Secondary feedstock requires documentation that it comes from forests with a verified low risk of non-compliance with standards for SFM.
4. Secondary feedstock requires documentation that it comes from forests with SFM certification at the forest management unit (FMU) level.

The four scenarios correspond to current SFM and verification requirements by the Dutch Verification Protocol under SDE+ for category 5 biomass (1), controlled biomass (2), category 2 biomass (3) and category 1 biomass (4), respectively. The assessment was based on peer reviewed literature, reports, information from certification systems' websites, and, to some extent, anecdotal evidence obtained from personal communication with key actors.

Technical feasibility: We found that supply chains for secondary feedstocks are often very complex; far more complex than those for primary wood or residue materials. The first source of this complexity is the number of involved actors. This is especially pronounced in SE US, where hundreds of non-industrial private forest land owners (NIPF) may supply a number of wood dealers, who act as middlemen between loggers and sawmills, and play a significant role in aggregating fiber supplies. Hundreds of economic operators may thus be involved in one supply chain that may consist of up to seven links or more, from the forest management unit to the energy production plant. Since 1990-1991, the Baltic countries have been through drastic economic and political transitions, with privatization of larger forest areas and an increasing number of NIPF. The large number of actors involved in the long supply chains in both SE US, and probably also in the Baltic countries, makes it a challenge to find common ground around certification. A second source of complexity is the number of points where mixing and aggregation of material flows takes place, often in each link of the supply chain, with an increasing number of feedstock origins in the aggregated material, as you move down the supply chain toward final markets. As certification (Scenario 4) and other documentation, including risk-based approaches (Scenario 2 and 3), requires a segregation of certified/controlled biomass from undocumented biomass, residue flows that were not separated before may now need to become separated. Third, to keep track of biomass with different sustainability properties, certification also requires that

actors set up and maintain a mass balance (MB). A mass balance is an administrative system that keeps track of inflows and outflows of materials documented to meet a specified standard. This requires skills that often cannot be easily acquired or afforded financially, especially for smaller actors, for example, computational skills or setting up and maintaining required management systems and documentation files. The complexity of the supply chain has different implications for the technical feasibility of the four policy scenarios. Scenario 1 is most technically feasible, as no documentation is required for the secondary residues, except the point of origin of the secondary feedstock generator. The same would be the case for Scenarios 2 and 3, if all 'controlled biomass' and SFM indicators, respectively, had been assessed with low risk. 'Controlled biomass' include FSC Controlled Wood, PEFC Controlled Sources, and 'controlled biomass' under the Sustainable Biomass Program (SBP). If some indicators are assessed with specified risks, the wood pellet plant will need to involve upstream actors for the provisioning of additional documentation that there is low risk of violating these indicators. It may vary from country to country how feasible it is to get this additional documentation. For scenario 4, comprehensive documentation of SFM should be provided by the forest owners to satisfy downstream customer's CoC document needs, which is technically feasible, but also here, financial and administrative resources, and skills, are needed.

Economic feasibility: Studies have been conducted that show what motivates economic operators to become certified and what issues may occur as barriers; economic arguments are nearly always involved in one form or another. In both the SE US and the Baltic forest sectors, economic actors seem to react, first of all, to the demand and requests of their customers. As the largest share of the sawmills' and secondary wood processors' revenue comes from lumber and wood products, respectively, the incentive to become certified first of all depends on the demand for certified lumber and wood products. Secondary residues will, generally, only constitute a minor part of the income and will therefore not provide a strong incentive to become certified. However, local exceptions might include areas where a pellet mill is the only significant consumer of forest biomass. Second, the possible physical separation of material flows and setting up the MB will also require economic resources. Most commonly, these resources cannot be made available by smaller actors, if only based on the current profit margins from selling secondary residues. There is little evidence that adequate price premiums exist for certified forest products. Yet, recent trends in the SE US show that pellet producers can stimulate landowners to become certified by setting quotas specifying the percentage of feedstocks that come from certified FMUs. Incentives developed by pellet mills also include provisioning of financial and technical support for getting certified via a group certificate administered by the pellet plant. In any case, economic theory suggests 'green product' price premiums might be effective motivators for landowners choosing to become certified. If 'green product' premiums are low, feedstock producers may be happy to sell into uncertified lumber or wood pellet markets. In the SE US, there is a modest domestic market associated with small wood pellet stoves for uncertified wood pellets. However, EU member state demand for pellets along with applicable sustainability standards dominates the total production in the region. In the Baltic countries, the wood pellet production is mainly focused on export to other European countries, with less opportunity to shift to uncertified markets. Economic theory also suggests tax exemptions for certified forests may provide an economic incentive for forest owners to become certified. However, in the SE US, tax breaks for maintaining forest cover and associated conservation values generally do not also incentivize becoming certified. Larger private industrial forest landowners in the US have shown that they are able and willing to bear certification costs, mainly motivated by access to markets that demand certification. In addition to FMU certification, most traded forest products, accounting for 70% of the wood flows in the US, are certified to the Sustainable Forestry Initiative's (SFI) Fiber Sourcing Standard (SFI, 2017). However, the amount of forests certified at the FMU level remains low in SE US and in US as a whole (16-19%). The share of the forest area that is certified in the Baltic countries is somewhat higher (>50%). Drivers of the certification process were pressure from international and national NGOs and

subsequently emerging markets and demands for certified products. The state forest in all three Baltic countries was certified to FSC in the early 2000s and later, in Estonia and Latvia, also to PEFC. This has likely helped to improve the reputation of Baltic forestry abroad, after a period with illegal logging especially in private forests, following the collapse of the Soviet Union. However, also in the Baltic countries, there is a limited uptake of certification among the many new private forest owners. Apart from the important economic barriers, due to costs of certification being relatively high for NIPF, another barrier to their certification is also that continuous forest management is hardly feasible on some of these small forest areas, at least not without structures that facilitate a well-functioning supply chain.

Cultural feasibility: Cultural factors are certainly a major barrier to certification in SE US, where especially NIPF are known to be suspicious of and reluctant to deal with outsiders. The certified forest area among NIPF remains <1% in this area. Furthermore, these forest owners generally disfavor certification systems led by environmental NGOs. In East-European countries forest regulations under the Soviet period were very prescriptive, and studies show that legislative requirements are largely covering certification requirement. This may ease forest certification. However, private forest ownership did not exist and traditional ways of managing private property were forgotten during years with nationalized forests, a process that started during the independent period in the 1920s. During the transition period after 1990, substantial re-privatization took place, and the number of NIPF is now very large in all three Baltic countries. These new owners are poorly organized with variable levels of knowledge about forest management. As in SE US, these new private forest owners generally disfavor systems led by environmental NGOs. These factors may altogether be barriers to getting these forests certified. In SE US and the Baltic countries, there is furthermore large variability in small forest owners' management goals and many of these do not align with a continuous delivery of timber to sawmills or residues for wood pellet plants. Decade-long work with implementation of water quality BMPs and logger training programs in SE US means that some level of confidence and collaboration has been established with some proportion of the private forest owners, but it is questionable how many more FMUs will become certified. Prospects are probably also poor for getting small forest owners certified in the Baltic countries. Experiences from Romania indicate that changes towards more certified forest areas are incremental at a slow rate, and that it takes many years to make significant change.

Pressures on forests: Even without FMU level certification, historical records showing a net increase in the forest area over the last 50 years suggest it is not likely that production of wood pellets from secondary residues will cause increased pressure on forests in SE US. The main drivers of the relatively limited deforestation in this region, as well as in other industrialized countries, are urban development and infrastructure. Conversion to agriculture also occurs where laws do not prohibit such conversion, as in SE US. However, conversion of agricultural land to forest also takes place and counterbalances deforestation. The main drivers of the trends in SE US forest management, including forest cover changes, are market developments in the timber and pulp and paper markets. If the wood pellet industry, against expectations, affects the forest land use and land cover, it is more likely that the demand for forest wood will provide incentives for keeping the land forested, and create new markets for forest wood, especially where pulpwood markets are limited or no longer exist. In the Baltic countries, the forest area is increasing at a high rate, on average 6% from 1990 to 2015, and the FSC centralized national risk assessments for Controlled Wood indicate that the risks of illegal logging are limited. Wood fuels constitute about 12.5% of the value of wood exports, but there are no immediate indications that these products are driving changes in the forest management.

Scenario 2 will likely be technically, economically and culturally feasible. Needed information about the country of harvest is included in the current requirements of EU Timber Regulation for imports

to the EU. We consider it unlikely that FMU level certification will increase significantly on private forest land, while risk-based approaches to verification of SFM have some potential, maybe especially in the Baltic countries, in the long-term. We generally see no signs or dangers that deforestation and forest degradation will take place in SE US or the Baltic countries, and consider it unlikely that requiring verification of SFM criteria for secondary residues will have a significant impact on forest management. Secondary residues are a byproduct from processing of primary wood into lumber and wood products, and as long as there is no pull to verify SFM requirements for these economically most important products, the anticipated gain associated with verifying SFM requirements for secondary residues will likely be limited.

Feasibility of four policy scenarios, in summary.

Policy scenario	Feasibility assessment
1. Secondary feedstock does not require documentation of compliance with any SFM standard	*Technically, economically and culturally feasible.* Needed information about the country of harvest is included in the current requirements of EU Timber Regulation for biomass imported to the EU.
2. Secondary feedstock requires documentation it comes from non-controversial sources (controlled biomass), using a risk-based approach to verification.	*Possibly technical, economically and culturally feasible*, also in a larger scale than currently, especially if relevant indicators are assessed with low risk in jurisdictional FSC risk assessments for controlled wood (Scenario 2) or in risk assessments for SFM by other systems (Scenario 3). A main technical and economic barrier to implementation is likely to occur if physical separation of SFM compliant and controlled biomass from other non-documented biomass is required, especially if flows of lumber and wood products have not already been separated in the same manner. Also, if some indicators are assessed with specified risk, as is currently the case for FSC Controlled Wood (Scenario 2) and SBP SFM risk assessments (relevant to Scenario 3), both in SE US and Baltic countries, additional documentation would be needed from suppliers of secondary residues. SBP has been successfully implemented especially for wood pellet plants in the Baltic countries, also for secondary feedstocks. It seems the success is due to persistent efforts in setting up mitigation measures, and that this has been possible based on close contact with suppliers, sometimes achieved through long-term efforts to build up the relationship. Pellet plants are thus able to acquire specific supplier information for each consignment, and suppliers have agreed to second party auditing, for example four times per year, and third party auditing, usually once per year. There are also examples of successful implementation of the SBP system in SE US, probably also building upon previous efforts in working with suppliers due to existing systems in place. It is thus important for pellet producers and sawmills to work together to comply with the required auditing and overcome economic and cultural barriers. This might be easier when fewer feedstock suppliers are involved, and when the pellet mill takes as much economic and administrative responsibility as possible. Note that Scenario 2 will likely be easier to achieve, due to less sustainability requirements for 'controlled biomass' compared to SFM compliant material (Scenario 3).
3. Secondary feedstock requires documentation it comes from sustainably managed and harvested forests, using a risk-based approach to verification	
4. Secondary feedstock requires documentation it comes from forests with SFM certification at the FMU level.	*Not technically, economically or culturally feasible in SE US at all, and probably also not in the Baltic states.* Wood dealers, sawmills and secondary processors will need full Chain of Custody certification for Scenario 4, and forest owners will need full SFM certification to FSC standards or equivalent. This is unlikely to happen, especially certification of a substantial proportion of the private land owners in any geographic region, unless there is already a market for certified sawn timber, which already physically separates wood flows when needed. The low volumes and value of secondary feedstocks going to certified markets are unlikely to provide adequate economic incentive for sawmills and secondary wood processors to become certified. High price premiums or tax exemption for certified forest may help, to some extent. For small private forest owners in both SE US and the Baltic countries, there will be additional barriers to overcome. These include management goals to which certification is not important, poor organization e.g. in forest owner associations, and reluctant attitudes, especially if this means compliance with systems that are administered by environmental NGOs. In spite of various efforts, only 0.2% of the forest land owned by non-industrial private forest owners in the USA was enrolled in a forest certification system in 2012, even if they own 35% of the forest land in the US, and 58% of the forest land in SE US.

1 Introduction

In the last decades, several European countries have increased the share of bioenergy in their energy mix, in order to meet their goals for greenhouse gas emission reductions and renewable energy. As European imports of biomass and bioenergy products have increased, concerns over sustainability have grown. The European Union (EU) Renewable Energy directive, adopted in 2009, therefore included sustainability requirements for liquid biofuels (RED I, EC 2009). However, no agreement was reached on mandatory requirements for solid biofuels. Instead, a report from the European Commission (EC) from 2010 encourages Member States to implement national sustainability criteria for solid biomass used for heat, cooling and electricity (EC, 2010). At present, United Kingdom, Denmark, Netherlands and Belgium are in the process of implementing national sustainability requirements (Mansoor et al. 2016).

In the Netherlands, the government and 47 organisations and interest groups signed the Dutch *Agreement on Energy for Sustainable Growth* in 2013, which sets goals to increase the share of renewable energy in the total energy mix from 4.4% in 2013, to 14% in 2020 and 16% in 2023 (SER, 2013). In connection with the conclusion of the agreement, a 'Covenant' was agreed between the Dutch energy industry and NGOs on the sustainability requirements for biomass used for energy (SER, 2013). The 'Covenant' stipulates that the requirements for Sustainable Forest Management (SFM), after a transition period, should be met via *Forest Stewardship Council* (FSC) or equivalent certification. It was also stipulated that this requires certification at the forest management unit (FMU) level, and not at the pellet plant level (Fig. 1). A shared starting point for parties to the 'Covenant' was that use of secondary residues for wood pellets must not become a shortcut for getting around SFM sustainability requirements. However, there appear to be differing points of view among the parties about the interpretation of the 'Covenant' in how it should be implemented to fulfil its intent; whether SFM requirements should be verified for secondary residues; whether it is possible or not to track SFM certificates from the FMU throughout the supply chain for wood fuels based on secondary residues; and whether no verification of SFM requirements for secondary residues will lead to increased pressure on forests in sourcing countries, including deforestation, forest degradation and loss of biodiversity. The Dutch subsidy scheme for renewable energy, SDE+, does not require that SFM be verified for forests from which secondary residues originate (Netherlands Enterprise Agency, 2017). For secondary residues, SDE+ only requires documentation of greenhouse gas (GHG) emissions from the First Collection Point (FCP[1,2]) and downstream. The FCP is typically the pellet plant, but it may also be another operator in the supply chain, where the residues are collected and mixed from second residue generators, typically sawmills or secondary wood processing industries[1].

This report aims to qualify the discussion among NGOs and energy companies, with the specific objective to analyze wood pellet supply chains, in order to assess and clarify:

[1] Selected economic operators as defined in the VP:

- BP: the Biomass Producer, which is typically the wood pellet mill, who directly receives Category 1 and 2 biomass from the FMU. The BP further trades, distributes, or processes the collected biomass.
- FCP: The First Collection Point of Category 3, 4, and 5 biomass from the points of origin (PO), including secondary wood residues, such as sawdust. The FCP further trades, distributes, or processes the collected biomass.
- PO: Points of Origin, where Category 3, 4, and 5 biomass is produced. POs are not subject to verification, but may be audited during the FCP verification based on identified risks.
- EPP: The Energy Production Plant, which is also the subsidy recipient.

[2] The VP defines the following categories of solid biomass that may qualify for subsidy:

- Category 1: Woody biomass from large Forest Management Units (FMUs ≥ 500 ha) - Primary forest biomass feedstock.
- Category 2: Woody biomass from small Forest Management Units (FMUs < 500 ha). Primary forest biomass feedstock.
- Category 3: Residues from nature and landscape management. Primary feedstock.
- Category 4: Agricultural residues. Primary agricultural residue biomass feedstock.
- Category 5: Biogenic residues and waste flows. Secondary and tertiary biomass residue feedstock.

- if it is feasible to track and verify FMU level SFM certificates (FSC or equivalent) for secondary forest residue-based wood pellets used in Dutch energy production facilities, in a chain of custody (CoC) from the FMU to the Energy Production Plant (EPP);

- if not requiring FMU level SFM certification for secondary forest residues will result in an increased pressure on forests in sourcing regions.

Hence, this study addresses the residual flows from the wood processing industry, the so-called 'secondary residual flows', but excludes post-consumer wood waste, i.e. the so-called 'tertiary residual flows'. As secondary residual wood flows only exist due to harvesting of wood in the forest, the report also touches upon primary wood flows, but these are not the main focus. The considered secondary residual flows include sawdust, wood shaving and cut-offs etc. that may come from both primary and secondary wood processing industries. Geographically, the report focuses on southeastern United States of America (SE US) and the three Baltic countries, Estonia, Latvia and Lithuania. The two regions are already major sourcing regions for EU Member States importing wood pellets for bioenergy production, and they are also expected to become important sourcing regions for the Netherlands.

2 Methods

2.1 FEASIBILITY OF VERIFYING SFM

We developed a framework to analyze the feasibility of verification of SFM criteria for secondary wood residues and tracking SFM documentation and certificates down the supply chain. The framework consists of three components:

- Component 1: selection of relevant feasibility aspects for secondary residues.
- Component 2: four policy scenarios which include a range of verification options for SFM requirements applied to secondary residues.
- Component 3: identifying the actors in the supply chain where barriers to verification are most likely to occur.

These three components were combined into the final analysis framework, to provide a systematic, detailed description and analysis of the various barriers in each scenario, including the extent to which barriers occur with different actors in the supply chain, and due to which feasibility aspects (Fig. 3).

Component 1

A feasibility study is an analysis and evaluation of a proposed project to determine its feasibility in different aspects, e.g. technical, operational, financial, economic, social, cultural, and legal aspects. The exact meaning of these concepts differs somewhat between research areas and study aims, and it is thus useful to define them for the particular context in which they are applied.

The overall focus of this study is the feasibility of verifying Sustainable Forest Management (SFM) at the Forest Management Unit (FMU) level and tracking the SFM certificates down the supply chain from the FMU to the Energy Production Plant (EPP). Based on the authors' own ongoing research and communication with policy, industry and civil society organizations around sustainable bioenergy and certification, we consider that possible barriers to verification of SFM at the FMU level will most likely be technical, economic or cultural in nature. Further clarification and documentation on which other types of barriers that could be important is beyond the scope of this report. For the purpose of this study, we define and understand these feasibility aspects as follows:

- *Technical feasibility means sustainable and non-controversial forest biomass is available, and that biomass flows can be physically separated, when required, and controlled by Mass Balance (MB) for the relevant parts of the supply chain, together with the associated sustainability documentation. These measures can be implemented by 2020-2022, if all other circumstances are favorable, including company capacity and expertise.* A mass balance is an administrative system that keeps track of inflows and outflows of materials documented to meet a specified standard. Undocumented biomass cannot be part of the MB, while certified and controlled biomass must be included separately in the MB accounting, even if physical separation is not necessary. The physical separation of undocumented biomass can be a major challenge. Controlled biomass is primary biomass for which there is a verified low risk of not meeting certain minimum sustainability criteria that are a subset of full SFM standard[3]. The aim is to verify low risk that the non-certified wood, mixed in with certified wood, is not 'controversial' (e.g. illegally logged wood).
- *Economic feasibility means that economic resources can be made available, so that solutions to document SFM can, in principle, be implemented by 2020-2022, if other circumstances are favorable. This includes resources to create the necessary capacity and expertise of the certified unit to carry out activities needed for certification.* Economic feasibility may be related to adequate market premium prices for certified products for each player in the supply chain. The possibly realized price premiums aggregating through the supply chain should finally be covered by the EPP, society or energy end-users. A biomass producer that is able to maintain positive profits without price premiums may also choose to get certified and carry the economic burden if this gives access to certified markets.
- *Cultural feasibility means that willingness exists in forest landowners, sawmills and other relevant actors to take the necessary steps to become certified or, if risk-based approaches are used, contribute with documentation that enables downstream actors to verify low risk of non-compliance for SFM indicators otherwise assessed with 'specified risks' in an initial risk-assessment4. Indicators assessed with 'low risk' require no further documentation than the information collected when conducting the initial risk assessment.* The necessary steps towards CoC certification for wood dealers, sawmills, and secondary producers include the willingness to use time, energy, and costs to physically separate undocumented wood from controlled sources and certified flows and set up an MB, also for secondary residues. These changes will often need to take place with help from professionals. For forest owners, the necessary steps include contacting a professional forester who helps to develop a management plan and gives guidance on how to make the changes to practices required by the certification standard, if these are not already part of the existing management. Next, a certification body must be contacted and paid for the conduct of the full certification process.

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[3] The VP sets the criteria for controlled biomass as a subset of those for SFM, including:

- Principle 3: Production of raw biomass may not result in the destruction of carbon sinks. All FMUs 1 & 2
- Principle 4: The use of biomass may not result in a long-term carbon debt. All FMUs 1 & 2
- Principle 5: Biomass production may not result in Indirect Land Use Change (iLUC). FMU ≥ 500 ha 1
- Criteria 7.1 Sites with high conservation values and representative areas of the forest types that are found in the FMU have been identified and are protected and where possible enhanced.
- Criteria 7.3 The conversion of forests within the FMU to other forms of land use, including wood plantations, is not permitted unless: the area concerned is small (the total converted area over the years is no greater than 5% of the area of the FMU on benchmark date 1 January 2008); and it clearly leads to long-term advantages for nature conservation; and there is no damage or threat of damage to areas with a high conservation value.

4 The VP explains its understanding of 'low risk' and 'specified risk' as follows: "The risk of non-compliance for each SFM criterion is expressed as 'specified risk' or 'low risk', based on the analysed information and application of the indicators set out in this protocol. For each SFM criterion, the rationale for risk designation shall be provided in relation to the information used. A 'low risk' is identified when there are clear indications that the chance of non-compliance with the relevant sustainability criterion in combination with the consequences is small and the risk assessment has yielded no information that leads to a 'specified risk' designation. A 'specified risk' is identified when there is not enough information for the risk assessment to establish whether the risk is low or when the mitigating measures are not sufficiently effective in reducing the chance that identified risks materialise or in reducing the consequences of such risks. In case of doubts a precautionary approach shall be applied."

Component 2

The four policy scenarios correspond to what is currently required for different biomass categories defined in the Dutch VP for the SDE+ renewable energy subsidy program (Netherlands Enterprise Agency, 2017)[2]. For the purpose of this study we assume that they in each scenario apply to secondary wood residues, which are included in Category 5 biomass, according to the VP. The four scenarios are:

1. Wood pellets produced from secondary feedstock do not require documentation of any SFM standards. A CoC from the FCP and downstream is required to document the country of origin of the PO, but no documentation of SFM (certified biomass) or avoidance of controversial sources is needed (with non-controversial biomass corresponding to 'controlled biomass' as defined by the VP). Also, documentation of the country of origin of the FMU is not needed. This scenario corresponds to VP requirements for Category 5 biomass, which is the category that includes secondary wood residues.
2. Wood pellets produced from secondary feedstock must come from forests with a verified low risk of non-compliance with standards for non-controversial sources ('controlled biomass'). A CoC from the FCP and downstream is required, with documentation of low risk that 'controversial sources' are included in the supply chain. This corresponds to VP requirements for 'controlled biomass' (Fig. 2).
3. Wood pellets produced from secondary feedstock require documentation that the feedstock comes from forests with a verified low risk of non-compliance with SFM standards. A CoC from FCP and downstream is required, with documentation of low risk of non-compliance with SFM standards for materials included in the supply chain. This corresponds to VP requirements for Category 2 biomass, which is primary materials from forests <500 ha (Fig. 1).
4. Wood pellets from secondary feedstocks must come from forests with SFM certification at the FMU level. A CoC is required from the FMU and downstream, with documentation of compliance with SFM standards at the FMU level. This corresponds to VP requirements for Category 1, which is primary materials from forests >500 ha (Fig. 1).

Note that application of Scenario 3 or 4 requires that also the verification method outlined in Scenario 2 is used, to show low risk that secondary residues mixed in with certified material are from controversial sources. The amount of 'controlled biomass' mixed in with the SFM documented biomass is controlled in the mass balance (MB), see also section 3. However, here Scenario 2 is also used as an independent scenario that expands Scenario 1, which only requires documenting the origin of the biomass, to documentation of low risk of mixing in 'controversial sources'.

For Scenario 3 and 4, it is thus assumed that the full set of Dutch carbon and SFM requirements applies also to secondary residues. This set of requirements is given by principles P3-11 of the VP. The Dutch requirements for 'controlled biomass', as defined by the VP, are assumed to apply to secondary residues in scenario 2. These include principles P3 (wetland drainage and conversion, conversion of natural and semi-natural forest to plantations), P4 (maintaining forest carbon stocks in the medium-long term, avoiding harvesting of stumps, and using less than the harvested volume for energy), P5 (avoiding indirect land use change, iLUC), and, under P7, criteria 7.3 (conversion to other land uses, including plantations) and 7.1 (protection of high conservation value areas)[3]. It is also assumed, as for primary feedstocks, that 'controlled biomass' can be mixed in with biomass that is compliant with the full set of Dutch SFM requirements, with a minimum of 70% SFM compliant biomass and a maximum 30% controlled biomass in the mixture used by the EPP (Netherlands Enterprise Agency, 2017).

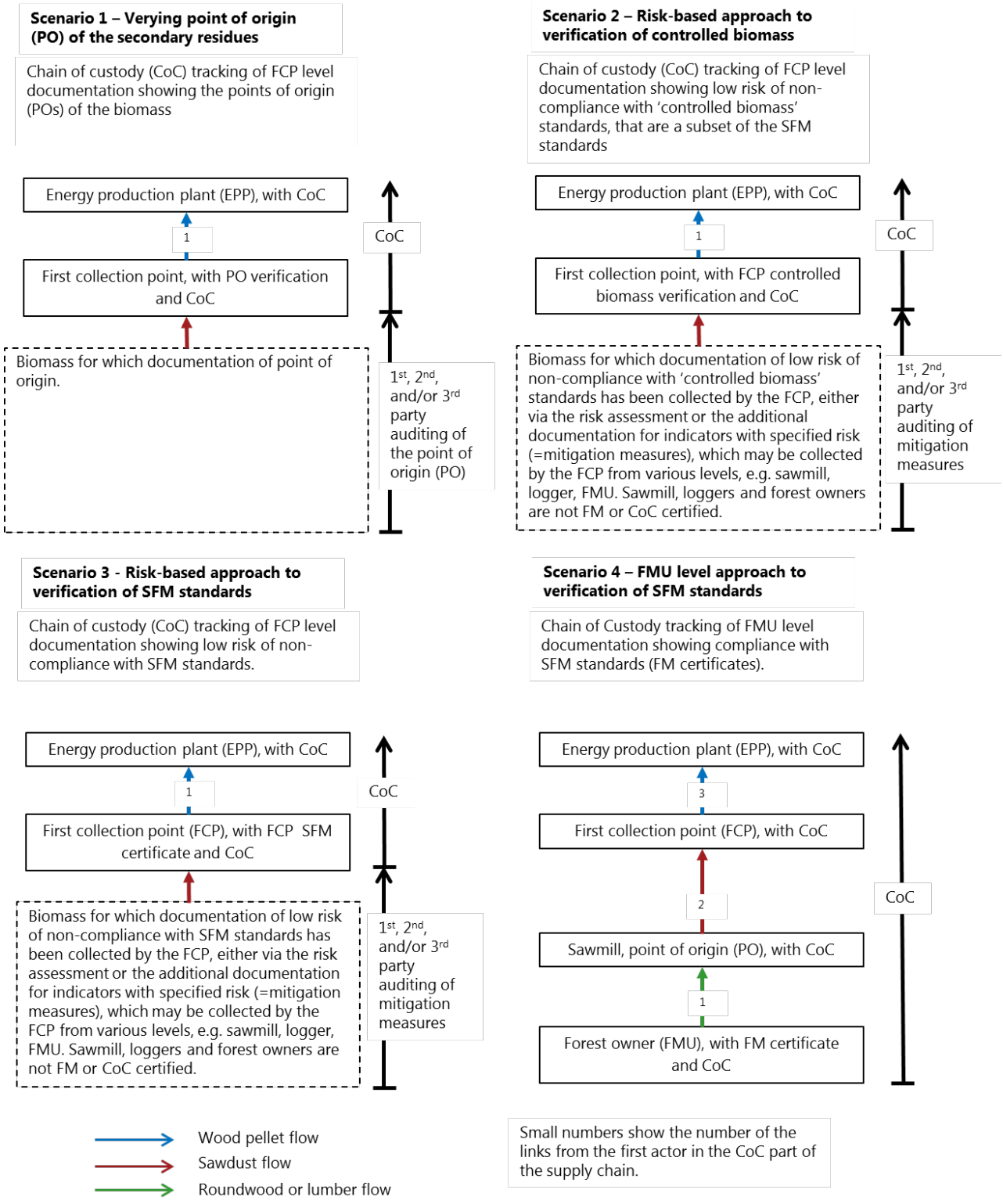

Figure 1. Illustration of the differences in sustainability requirements' and verification approaches between Scenario 1, 2, 3 and 4, for a simplified bioenergy supply chain using secondary residue-based wood pellets as fuel (for co-firing). In Scenario 1, there is no SFM requirements, while Scenario 2 have requirements for a limited subset of SFM requirements (avoiding controversial sources). Scenario 3 and 4 both have requirements for Sustainable Forest Management (SFM), but they use different approaches to verification. For an indication of the steps of the risk-based assessments used in Scenario 2 and 3, see Fig. 2

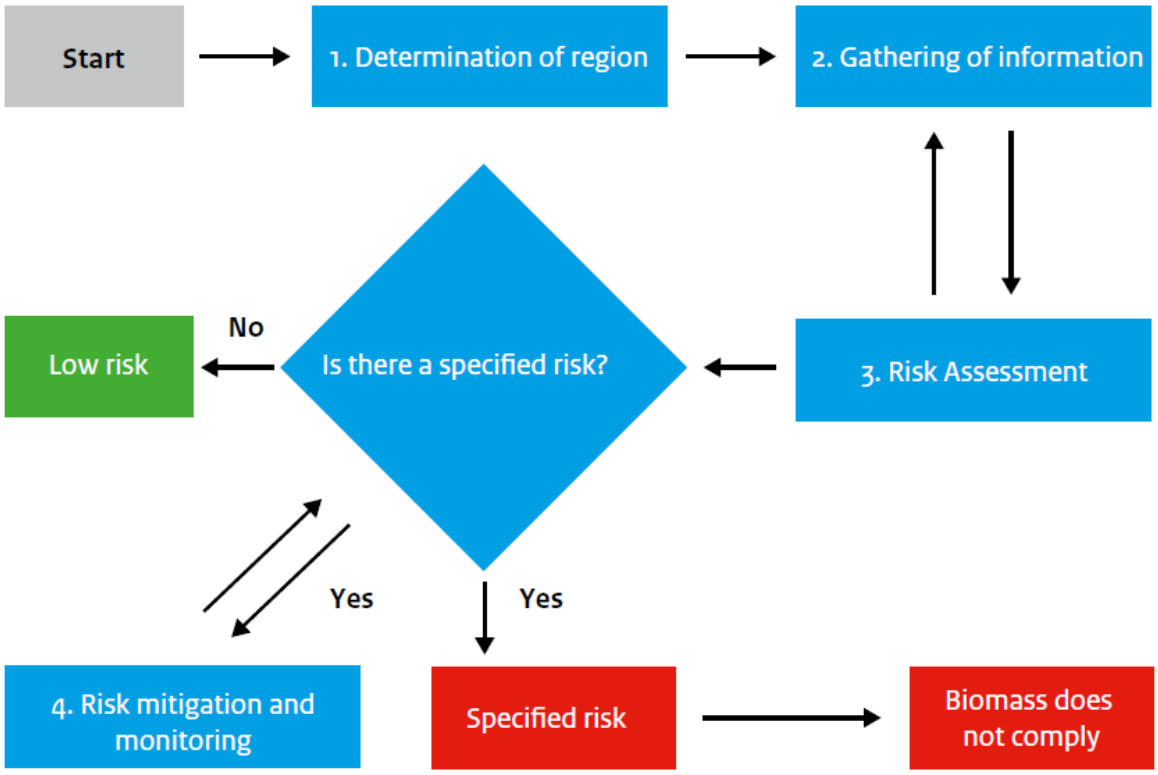

Figure 2. Illustration from the VP (Section 8, p. 40) showing the steps for biomass producers to demonstrate compliance with SFM using risk-based assessment.

Component 3

Based on information obtained from communication with policy, industry and civil society actors, we suggest that challenges related verification of SFM requirements for secondary wood residues, and tracking of SFM certificates down the supply chain, are potentially largest for upstream actors, including forest, loggers, wood dealers, sawmill owners and secondary wood processors. Analysis of barriers for actors further downstream in the supply chain is beyond the scope of this report.

Temporarily, various private certification systems are accepted as proof of compliance with the Dutch criteria, depending on the exact sustainability principle (see Table A1 of Annex A for more details, and the VP's Table 3[5]). We use experiences from these systems to discuss the feasibility of implementing SFM criteria for secondary residues via Scenario 2, 3 or 4, using Scenario 1 as a reference. Information about such experiences has been retrieved from the following types of sources:

[5] Certification schemes and the principles for which they may be used to demonstrate compliance during the transitional period, until end of 2022 (VP, section 2.3, including Table 3, and section 10.1):

- For carbon and forest criteria (P3-P11): FSC and PEFC;
- For soil quality criteria (P2): FSC, PEFC, and EU recognized schemes for biofuels, e.g. ISCC-EU or NTA8080;
- For emission calculations (P1): EU recognized schemes for biofuels, e.g. ISCC-EU or NTA8080, Biograce-II;
- For Chain of Custody (P13-P14): FSC, PEFC, SBP, GGL and EU recognized schemes for biofuels, e.g. ISCC-EU or NTA8080.

- Peer review literature and reports.
- Standards, documents and other information from certification systems' and certifying bodies' websites, including standards and other information about how the systems function and the extent of their implementation (number of certificates in different regions for certain types of products).
- Personal communication, where no written documentation was available, with reservations that this can only be considered as examples and anecdotal evidence.

We refer to Table 1 of the Dutch Verification Protocol (VP) for terminology associated with categories of biomass[2] and economic operators[1] (Netherlands Enterprise Agency 2017), and to the Glossary of Terms and Definitions of the Sustainable Biomass Partnership (SBP) for other terminology (SBP 2015)[6]. Abbreviations of regulations and certification systems follow the general convention[7], but see also Annex B.

[6] SBP definitions (SBP 2015) of:

- Primary wood processing: Any processing that transforms roundwood into materials other than roundwood.
- Secondary wood processing: Any processing that transforms the products of a primary wood processor

7 Abbreviations for key regulations and certification systems:

- EUTR: EU Timber Regulation: Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market.
- FSC: Forest Stewardship Council
- PEFC: Programme for the Endorsement of Forest Certification
- SFI: Sustainable Forestry Initiative, endorsed by PEFC for the USA and Canada.
- SBP: Sustainable Biomass Program
- GGL: Green Gold Label

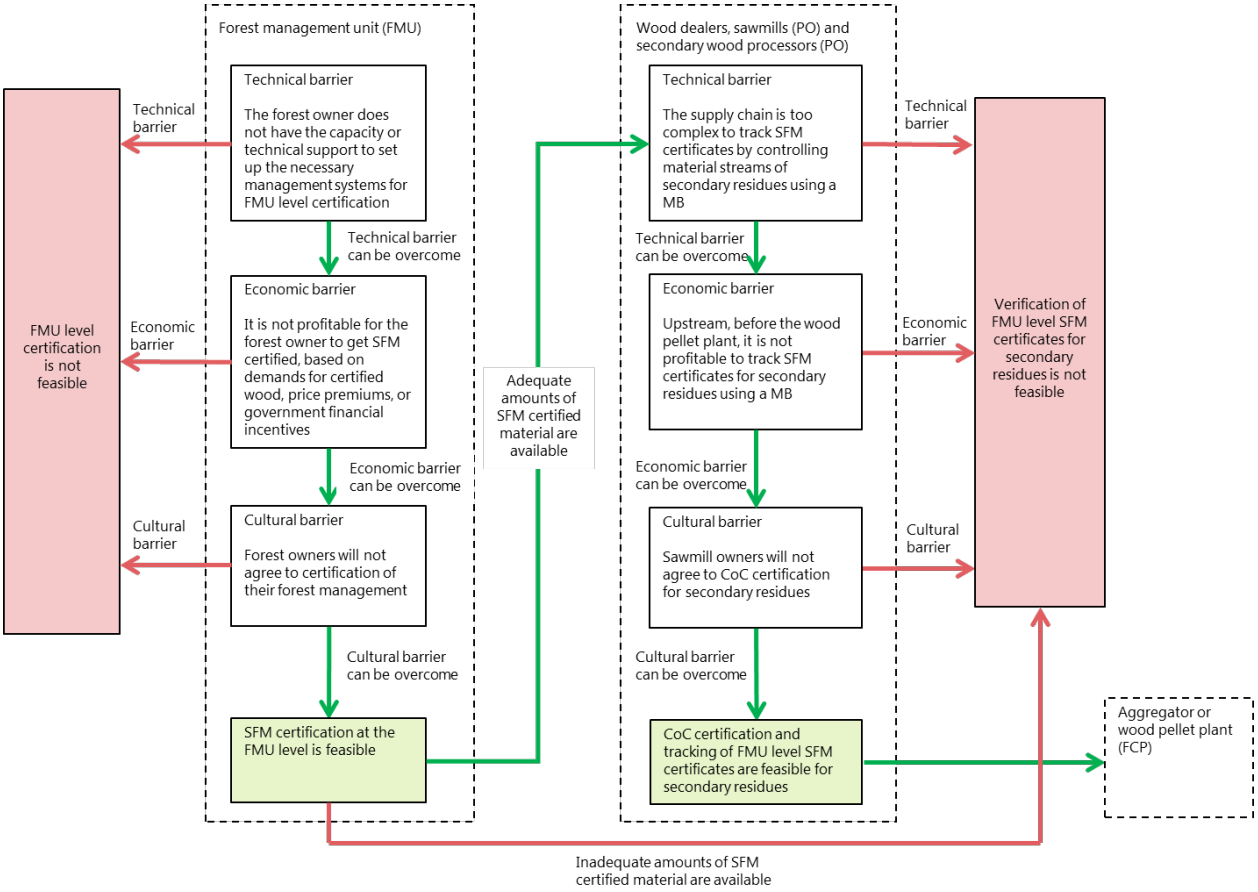

Figure 3. Conceptual diagram for understanding and assessing the feasibility of verifying Sustainable Forest Management (SFM) requirements for secondary residues used to produce wood pellets and tracking SFM certificates in the first part of the supply chain, as required in Scenario 4, cf. also Fig. 2. A similar approach was taken to analyze feasibility in Scenario 2 and 3, where challenges in this part of the supply chain would be limited to collection of upstream documentation for mitigation measures and, in the absence of a chain of custody (CoC), the origin of the biomass.

2.2 PRESSURES ON FORESTS

Some of the major concerns expressed in the media and from civil society organizations in relation to forest biomass harvesting for energy are deforestation and conversion of natural forest to plantations. These have also been concerns in the Dutch debate. A change in forest area occurs when the forest is removed to use the land for other purposes then forest, for example for cultivation of crops, cattle grazing, urban development or infrastructure. A change in land cover occurs when forest managers choose to apply activities, which change the tree species or the tree species composition. The change could also involve a change in regeneration methods, thinning strategies, rotation ages and other characteristics of the silvicultural system. Another concern has been if forest biomass harvesting would lead to destruction of high conservation value forest areas and general loss of biological diversity. In many countries, a large part of the biological diversity is associated with forest habitats.

These issues were lately reviewed for SE US by Dale et al. (2017) in relation to wood pellet production generally, not only secondary feedstocks. We used this review as a starting point for examining the trends and dynamics in land uses and forest covers and the drivers of change, with the aim to see if lack of SFM requirements for secondary residues might be an important factor. Using findings by Dale et al. (2017) as a starting point, we also examined the main threats to high conservation values, focussing at old-growth and

bottomland forest, which are the forest types of main concern, and touched upon the conservation of biodiversity in managed forests and forest landscapes. Again, the aim was to see if lack of SFM requirements for secondary residues could lead to significant threats. The same issues were examined for the Baltic countries, with the same aims. In this case, the so-called Woodland Key Habitats (WKH) are the forest types of greatest concern, in relation to high conservation values.

3 Technical feasibility

Assuming that SFM material is available, the tracking of FMU level SFM certificates from the FMU to the sawmill and the wood pellet producer (FCP) and further on to the energy production plant (EPP), for wood pellets made from secondary residues is possible in simple supply chains (Fig. 1). However, the supply chain complexity is often high, and there may be >7 links from the FMU to the EPP (Fig. 4). Preliminary results from SE US show that wood pellet mills typically source their secondary feedstock from 15-60 sawmills, 10-15 secondary wood processors, involving sometimes up to 45 wood dealers, that are working with more than 400 land owners (Kittler et al. 2017, Fig. 5). The logs feeding each sawmill thus might come from multiple wood dealers that work with a larger number of forest owners. These complex wood dealer systems in SE US developed in a specific economic, legal, and cultural context, which perhaps makes the system unique to SE US (see Frick et al., 1985, for the case of Mississippi). Carter (2014) explains that wood dealers organize the fragmented forests owned by a diverse group of individuals and organizations into a reliable supply chain: The dealer buys trees from the landowner, contracts with independent contractors to harvest and deliver the timber (loggers), and sells the harvested trees to the wood consuming facility. About 20% of the dealers control 80% of supply, and buyers prefer to work with dealers (those in the 20%) who are known for good working relationships with both facilities and landowners[8] (Carter, 2014). In Latvia, a plant uses about 50% primary, 40% secondary, and 10% of tertiary residues (wood waste), involving also a large number of actors (M. Jugaste, pers. comm.).

The secondary residues from sawing logs from a large number of forest owners get mixed and aggregated at the sawmill. Further mixing and aggregation takes place when the lumber is processed into wood products, as secondary wood processors purchase their wood from several sawmills. Additionally, aggregators might buy sawdust and other secondary sources for re-sale to pellet plants and other users. There are also examples where wood pellet plants function as aggregators for other smaller pellet mills (B. Kittler, pers. comm.). The complexity of wood pellet supply chains based on secondary feedstocks is thus considerably higher compared to forest energy supply chains mainly based on primary feedstocks, even supply chains based on primary feedstocks may also involve a large number of forest owners and harvesting locations, where aggregation may take place a storage and chipping sites (Flisberg et al. 2010). High levels of complexity are pronounced in SE US, but since the post-1990 transition of the economy in the Baltic countries, they also have a considerable amount of small private land owners (Actiņš and Kore 2014, Brukas 2015, Põllumäe et al. 2014) that are a challenge when aiming to establish reliable supply chain and furthermore verify SFM.

With these material flows, from forest owners to wood dealers, sawmills and secondary manufacturers that often involve hundreds of actors, the different consignments will typically have different documentation of different sustainability characteristics and claims associated with them, and some will be without any documentation. If operators need to track volumes with different sustainability characteristics, three main strategies can be applied. First, if there are adequate amounts of sustainability documented material in the

[8] Carter (2014) further explains that some Timber Investment Management Organizations (TIMO) and Real Estate Investment Trusts (REIT) act as direct suppliers of wood fiber, which eliminates the stumpage contract process and allows corporate owners to enter into contracts with wood consuming facilities and harvest and transportation contractors directly.

market, it can be decided to only use suppliers that deliver material with the required sustainability characteristics. Secondly, the operator can physically separate the consignments. Finally, they can use MB (mass balance), which is especially applied where there is continuous or batch production processes, as in wood pellet production. Typically, the so-called volume credit method or the percentage based methods are used to keep track of certified and controlled wood in the MB[9]. These calculation methods permit certification claims to be made about sustainability characteristics, based on agreed rules that ensure balancing of sustainability credits or percentages, so that sustainability documented inputs equals sustainability documented outputs from the mill or manufacturer over a certain period of time, for example three months. However, the physical sustainable feedstock inputs are not directly linked to the physically outgoing sustainable biomass in short time periods, for example in a certain week. It means that the physical feedstock may leave the facility at a different time than certification claims with which it arrived. However, FSC, PEFC and VP CoC rules restrict the length of the period between physical arrivals and outgoing claims to a certain maximum time, so that balance is required over each period of, for example, three months. This mechanism is essential for making the system work in practice, when there are also rules on the maximum proportion of controlled biomass relative to the certified, SFM compliant biomass. Furthermore, physical separation of certified and controlled biomass from non-documented biomass will typically be needed, if non-documented material is also received by the wood processing facility. With the time and costs possibly needed for physical separation, it may easier and cheaper for sawmills to exclude non-documented materials from their wood supplies, or seek markets that do not require sustainability documentation.

The implications of complex supply chains and accounting rules differ among the four policy scenarios. Based on the information available, our assessment is that:

Scenario 1 is technically feasible throughout the supply chain, and the probability of making the change to scenario 1 by 2020 is very high. The auditing requirements at the FCP are limited to checking if basic information, such as the country of origin of the secondary feedstock, is correct (see Table A2 of Annex A for more details). This typically means that the wood pellet plant must document from which sawmills and manufacturers they received their secondary feedstocks. If no other systems were in place, the fact that no other checking is required upstream from the FPC might in theory create a loophole for secondary residues, as unsustainable material could enter the supply chain further upstream from the FCP. For biomass important to EU markets, however, this is part of the supply chain would be covered by the Due Diligence System (DDS) required under EU Timber Regulation (EUTR, EC 2010) (NEPCon 2017, NEPCon 2018), with the actor placing wood on the European Union markets being responsible for setting up a DDS. The DDS also cover wood chips and wood pellets, whether based on secondary residues or not. Guidelines to NEPCon's (2018) LegalStandard, which cover EUTR requirements, require that the DDS identify risks that the biomass is not legal, categorise the risk, and finally, mitigate it in case an indicator is categorized with specified risk. The appropriate mitigating measure depend on the type of potential legal non-compliance in question. Some specified risks can be mitigated by field visits to the harvesting sites (e.g. inspecting the borders of the harvesting unit, workers' use of personal health and safety equipment, level of soil damage). Low risk can also sometimes be justified based on mitigating document control (such as custom declarations forms, payment of royalties, work permits, etc.).

Scenario 2 is possibly technically feasible by 2020. The greatest challenge is probably the physical separation between 'controlled biomass' and undocumented secondary feedstock. Achieving the scenario also requires that adequate amounts of controlled primary feedstock are available in the market, as secondary residues is a by-product from their processing, with no subsidy schemes requiring compliance with controlled wood for other

[9] See e.g. FSC and PEFC Chain of Custody (CoC) standards, and the VP, for the technical details of the calculations, when using each of these approaches.

wood end-uses than energy. Making a change to Scenario 2 will probably become more feasible if FSC National Risk Assessments (NRA)[10] for Controlled Wood[11] (CW) NRAs and CNRAs are completed, especially if many CW indicators are categorized with low risk. Material attributed with low risk for all indicators only require documentation of the jurisdiction of origin. By 4 March 2018, an NRA or a CNRA has been approved for 16 countries (including Estonia, Latvia and Lithuania), and the process is ongoing in another 46 countries (including the USA). However, currently some indicators are assessed with specified risk in most countries, including indicators for HCV in the Baltic countries. These indicators have not yet been assessed for the USA. The expected times for completion of the NRAs and CNRAs have been postponed several times, indicating that unexpected challenges have occurred. As of 4 March 2018, expected times for completion are mid- or end 2018. For more details see Table A2 and A6 of Annex A , and FSC (2018). Until 2020-2022, FSC CW and PEFC 'controlled sources' (CS) are accepted by SDE+ as controlled biomass, which means that to some extent verified controlled biomass is available in the market. However, FSC CW and PEFC CS requirements are not fully identical to the Dutch criteria for 'controlled biomass', meaning that FSC CW and PEFC CS verification, in their current forms, cannot be used directly for verification of controlled biomass under SDE+ after 2022.

Scenario 3 may be technically feasible, but a challenge in the upstream part of the supply chain is again the physical separation between SFM compliant/controlled secondary feedstock and undocumented secondary feedstock. Only controlled feedstock can be mixed with SFM compliant material, not undocumented feedstock. It furthermore requires that adequate amounts of compliant and controlled primary feedstocks from risk-based certification systems become available in the market as it grows. Larger amounts are also required as the UK and Denmark's systems for sustainable wood in energy production are being phased in. Another challenge is that certification systems using risk-based approaches to SFM verification have only been accepted by SDE+ for their CoC (Sustainable Biomass Program (SBP) and Green Gold Label (GGL)). Evaluations of SBP and GGL by the Dutch authorities, for SFM verification of Category 2 biomass under SDE+, were overall positive, but approval could not be obtained without further developing the systems (ADBE 2018). Some of the risk-based systems, including also NTA 8080, may develop to include Dutch SDE+ requirements over time. GGL and NTA 8080 seem to intend to do so, generally, while SBP mainly expressed interest in developing their system for secondary feedstocks (ADBE, 2018), even if no SFM verification is currently required for Category 5 biomass. The SFI Fiber Sourcing program might hold potential as a system for North America, and the system is currently being evaluated by the Dutch authorities. However, approval would, as a minimum, require that SFI Fiber Sourcing develops into a dedicated risk-based verification system. However, SFI Fiber Sourcing documentation already contributes as documentation through SBP supply base evaluations (SBE), that sometimes use e.g. the SFI 'Certified Sourcing Implementation Manual' as a mean of verification, as was for example the case for the SBE of Enviva's wood pellet plant 'Cottondale' (see Table A2 of Annex A for more details).

Scenario 4 may be technically feasible, but not by 2020, as economic and cultural barriers are rather significant in the upstream part of the supply chain (see also section 4 and 5 and Table A3 of Annex A for details).

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[10] FSC National Risk Assessments (NRA) or Centralized National Risk Assessments (CNRA), depending on the body responsible its development. The responsible body in the case of the NRA is a FSC Network Partner, the FSC Regional Office, or FSC. The CNRA is a temporary assessment until an NRA can be established. The development of the CNRA is overseen by the FSC Policy Standards Unit, in cooperation with the national stakeholders.

[11] Under FSC Controlled Wood (CW), there are five categories of unacceptable material that cannot be mixed with FSC certified materials:

- illegally harvested wood
- wood harvested in violation of traditional and human rights
- wood harvested in forests in which high conservation values (HCVs) are threatened by management activities (HCVs are areas particularly worthy of protection)
- wood harvested in forests being converted to plantations or non-forest use
- wood from forests in which genetically modified trees are planted.

Scenario 4 requires that all feedstocks are SFM certified at the FMU level, and all downstream actors must implement a CoC (see also Table A2 and A3 for more details). Technically, it is much more challenging to keep track of secondary residues and its mix of sustainability claims compared to primary roundwood or primary residues. Sawmills and other upstream actors will often have to make changes in their practices and suppliers. Collaboration with some wood suppliers may need to stop if they are not willing change their practices or provide documentation as needed, when a specified risk has been detected. In order for these changes to take place, it is necessary that capacity and resources are available, including a viable business plan to cover additional new costs by various actors in the value chain (Qian and McDow 2013; see also section 4 in this report). Also, upstream actors must be willing to make the needed changes (see also section 5). Note also that FSC and PEFC are approved as evidence of SFM criteria of the SDE+ program, until the system is phased by 2020-2022. Evaluations of FSC and PEFC international, and SFI forest management, fiber sourcing and CoC standards are in process (ADBE 2018). If not approved, it might be a challenge to have these systems adapt to the SDE+ SFM requirements.

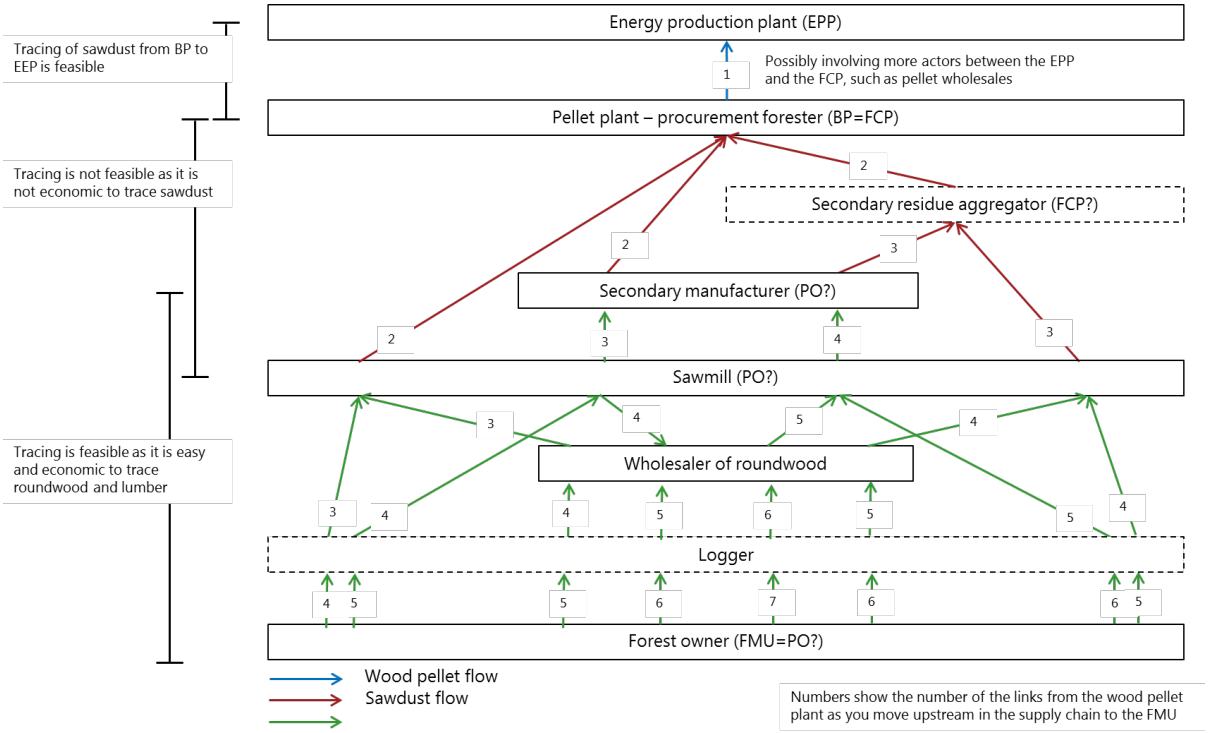

Figure 4. A complex wood pellet supply chain using secondary residues, such as sawdust, as feedstock. To the left, indications are given of the challenges to tracking FMU level SFM certificates in different sections of the supply chain.

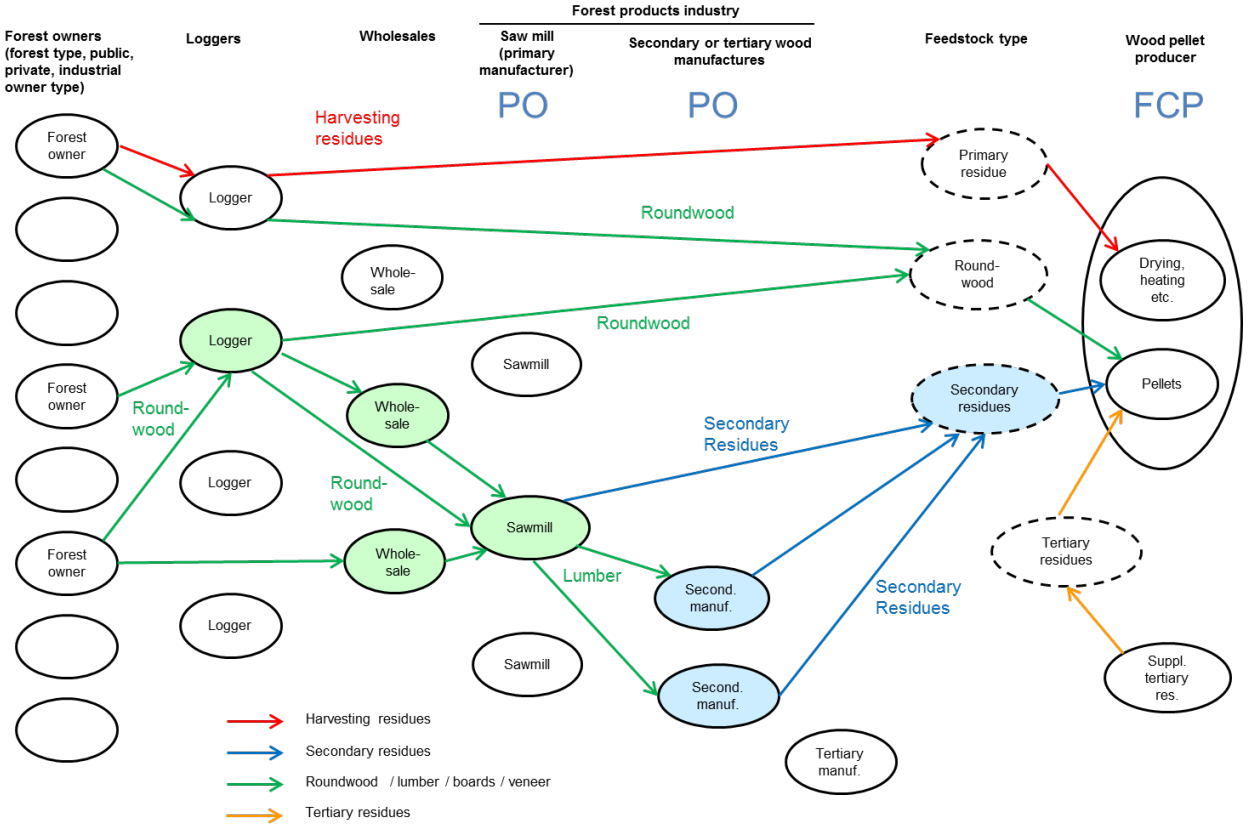

Figure 5. A complex wood pellet supply chain using sawdust as feedstock. Each pellet mill purchasing sawdust and other secondary residues may source from a much larger number than indicated in the figure, sometimes >60 sawmills, involving an even larger number of forest owners (Kittler et al. 2017).

4 Economic feasibility

The economic profitability and feasibility will differ among various approaches to SFM certification and verification, but also the forest owner structure may be an important indicator, e.g. how large is the share of public forest and how much forest is owned by industrial or small non-industrial private forest owners (NIPF).

Scenario 1 is economically feasible. The point of origin of the secondary feedstock will probably often be clear from documents, and otherwise possible auditing upstream from the FCP is limited to the claimed point of origin. For biomass imported to EU markets, EUTR and the associated DDS will require documentation of low risk of illegality, down to the point of harvesting (see Table A2 of Annex A for more details).

Scenario 2 is possibly economically feasible, but resources must be available upstream for possible physical separation of controlled secondary feedstock from undocumented feedstock, and enough controlled primary feedstock must be available. Forest and sawmill owners do not need to become certified, and in principle, the economic costs to upstream actors might be the same as for scenario 1, if all indicators for avoiding controversial sources are assessed as low risk. In practice, efforts to provide upstream documentation are typically concentrated to a few issues that have been assessed with specified risk (see Table A6 of Annex A for more details). There might thus be some economic burden for the upstream actors, from the FCP, depending on which indicators have been categorized with specified risk, what information is available for risk mitigation, and how comprehensive the needed mitigation measures are (see Table A2 of Annex A for more details).

Scenario 3 is economically feasible from the FCP and downstream, and possibly economically feasible for upstream actors at the current scale of exports from SE US and Baltic countries. Scenario 3 is maybe also economically feasible at larger scales, but resources must be available for possibly needed physical separation of compliant/controlled secondary feedstock from undocumented feedstock, and enough compliant/controlled primary feedstock must be available for processing into lumber, wood products and associated residues. The economic burden associated with Scenario 3 will typically be additional to that associated with Scenario 2, if additional SFM indicators are assessed with specified risk in the regional risk assessments (RRA) or, alternatively, in the supply base evaluation (SBE) for the individual pellet plant (see Table A7 of Annex A for details). The appropriate mitigating measures will depend on the type of specified risk in question. Currently there are no guidelines available from SBP or GGL on how to set up mitigation measures, but some types of specified risks might be mitigated by field visits to the harvesting sites, while it might be possible to mitigate other specified risks based on document control (see also NEPCon (2018), for guidelines on setting up mitigation measures for legality). As an example, a SBP certified wood pellet plant in Latvia needs to audit upstream actors four times per year, to ensure that mitigation measures are being properly implemented for biodiversity indicators 2.1.1 and 2.1.2 (Table A7), and the certification body will audit the pellet plant and possible upstream actors once per year (Mikhel Jugaste, pers. comm., see also Table A2 of Annex A for more details).

Scenario 4 is economically feasible from the FCP and downstream, but not for upstream actors, by 2020 or 2022, even if it may be possible to make progress in a long term if direct or indirect financial incentives motivating forest owners, loggers, sawmills and secondary manufacturers are adequately high. It is necessary that forest owners become SFM certified, and that wood dealers, sawmills, and secondary wood processors are CoC/CW or CoC/CS certified. Loggers, transport, storage, etc. only need CoC/CW certification if they buy the wood and thus take possession of the material. Currently, the perceived benefits of certification programs are not high and there is a lack of certified primary material. For example, primary wood manufacturers in Virginia saw no benefits of certification with regard to increased market share, exports opportunities, future demand, gaining a competitive edge, improving reputation or value added (Bond et al. 2014). In a survey of US hardwood lumber manufacturers, only 25% reported having benefited financially from FSC CoC certification (Espinoza et al. 2012). The economically most important driver for certification generally seems to come from customer demands in the most important markets, which are lumber, wood product and paper markets. These markets are the largest, both in the SE US (see Fig. A2 of Annex A) and the Baltic countries (see Fig. A3 of Annex A), both in volume and economic value. A demand and call for sustainability requirements from these markets is more likely to provide a significant economic incentive for upstream actors to get certified, compared to wood pellets markets based on secondary feedstocks. This is especially the case in SE US (Tuppura et al. 2016), but also in Eastern Europe (Trishkin et al. 2014). For example, certification has probably helped to improve the reputation of Baltic forestry generally, after a period with illegal logging, especially in private forests, following the collapse of the Soviet Union (Ahas et al. 2006, Hain and Ahas 2007, Bekeris 2011). Accountability, at least in state forestry, has thus become an important issue in the Baltic countries (Lazdinis et al. 2009). For the wood sector in Romania, a study shows that reputation is a strong motivator for chain of custody certification and that direct certification costs are of minor importance as a barrier (Halalisan et al. 2013), even if costs associated with chain of custody are still significant to some actors (Klarić et al. 2016). The wood pellet industry generally has negligible financial leverage to stimulate forest landowners, sawmills and manufacturers to become certified due to its demand for low value raw materials, which are partly by-products from manufacturing of higher value lumber and wood products (Dale et al. 2017). In a current example, a vertically integrated wood pellet and forest products company got FSC certified due to demands for certified pulp and paper and packaging products (B. Kittler, pers. comm.). However, local exceptions might include areas where a pellet mill is the only significant buyer of forest biomass (B. Kittler, pers. comm.). Even if wood dealers, sawmills and wood processors experienced economic benefit from certification, after having spent the necessary efforts and costs possibly needed to physically separate wood streams as needed, there is still a limited amount of certified wood available. Especially for small family forest owners, capacity and economic resources are a major barrier to certification. Studies show that the availability of financial assistance, among

other factors, positively affects the interest in forest certification in the US (Leahy et al. 2008, for Minnesota). Recent evidence also indicates that some pellet mills in the SE US have some success with addressing the economic needs of feedstock suppliers through setting up group certificates that provide financial and administrative support for forest owners to get certified (B. Kittler, pers. comm.). Another study shows that private forest owners generally do not reject the idea of having their forests audited, but they are not willing to bear the cost (Perera 2007, for Louisiana and Mississippi). However, Ma et al. (2012) found that financial incentives are not always the determining factor underpinning willingness to become certified, and suggest that certification companies should target those who already participate in cost-share programs, as those of the USA where state subsidy programs have been developed to support various forest management activities such as tree planting. For historical reasons, the SE US supply chain structures are very flexible for the sawmills and the burden of rapid change tends to fall on the wood dealers and landowners (Flick et al. 1985), which may explain why there is sometimes only little economic margin for mistakes or long-term considerations. Even if the conditions have improved, it may also be unlikely today that landowners will be able to carry the main part of the cost burden needed to document and satisfy the required sustainability requirements. While bagged wood pellets for residential use, with no sustainability requirements, are competitive with for example natural gas in the US, commercial use of wood pellets is not competitive and almost non-existent in the US, where it is not incentivised (Lamers and Hess 2017). The main consumers of US-produced wood pellets, apart from residential use, are export markets, which accounted for 63% in 2015 (Lamers and Hess 2017). Research conducted by Qian and McDow (2013) suggests that the main driving force behind this export is the competitive cost of wood pellet fuel under European countries' financial support schemes for renewable energy and fossil fuel taxes to reduce GHG emissions. Qian and McDow (2013) question to what extent the economic benefits received by European EPPs will flow back up through the links in the complex supply chains, and add adequate value for the many more players to finance documentation of sustainable practices. Widespread certification at the FMU level is unlikely to happen in SE US, unless, perhaps, if price premiums for certified materials are substantially increased (see Table A2 and A3 of Annex A for more details). Recent trends in the SE US show that pellet producers can stimulate landowners to become certified by setting quotas specifying the percentage of feedstocks that come from certified FMUs (B. Kittler, pers. comm.). Incentives developed by pellet mills also include provisioning of financial and technical support for getting certified via a group certificate administered by the pellet plant (B. Kittler, pers. comm.).

It is not clear from various studies how great the financial incentives must be for actors to engage. Anecdotal experience from Romania suggests that a tax exemption which outbalances the costs of certification may be adequate to persuade forest owners in this region to get certified, or if potential costs, for example fines for violation of legislation for worker safety, are balanced with needed new investments, in this case in new worker safety equipment (L. Nichiforel, pers. comm.).

5 Cultural feasibility

Studies indicate that cultural feasibility, as economic feasibility, depends on the size of the organization and also the general size distribution of organizations. For example, there is a significant difference in the interest in regulatory programs and incentivizing policies designed for provisioning of public benefits, depending on forest owner size in Georgia, USA (Poudyal et al. 2015). It has also been shown that the North American solid wood sector's interest in FSC CoC certification depends on the business size (Vidal et al. 2005). This pattern may be linked to the costs, which can often more easily be absorbed by larger organizations.

Another characteristic that may relate to the size of the forest owner is their management goals. While economic goals are likely prominent for larger corporate owners, there is large variability in small forest owners' management goals. In SE US, for example, many small owners have goals that do not align with continuous delivery of timber to sawmills or primary residues for wood pellet plants (Butler et al. 2017, Creamer et al. 2012, Leahy et al. 2008, Ma et al. 2012). The same is valid for large numbers of new forest owners in Eastern Europe (Stanislovaitis et al. 2017).

Cultural feasibility may also depend on the country or region. For example, small forest owners in SE US have historically been known to be suspicious of and reluctant to deal with outsiders (Flick et al. 2010). A study from Georgia, also suggests that land owners in this region prefer incentive-based voluntary policies over mandatory regulations as encouragement to provide public benefits from private forests (Poudyal et al. 2015). In another study examining incentives to harvest wood for energy, SE US respondents were less in favor of subsidies and grants, but also rules and regulations, compared to respondents from the rest of the country (Aguilar and Saunders, 2011). A study from Maine and New Brunswick showed that in these regions landowners may be more comfortable with environmental regulations than previously understood, and also that they may be interested in non-monetary incentives (Quartuch and Beckley 2014).

Based on these observations, it can be assumed that cultural feasibility will differ among the four policy scenarios:

Scenario 1 is culturally feasible. The point of origin of the secondary feedstock will probably often be clear from documents, and otherwise possible auditing upstream from the FCP is limited to the claimed point of origin. For biomass imported to EU markets, EUTR and the associated DDS will already require documentation of low risk of illegality, with possibly on-sites visits of harvesting sites only taking place if there are risks of certain types of non-compliances with legality (NEPCon 2018). Such risks are assessed to be low for the Baltic countries in their national SBP RRAs, and in SBP SBEs from SE US.

Scenario 2 is possibly culturally feasible at the current scale of use, and possibly also at a larger scale, depending on the regional risk profile. However, ongoing work with FSC NRAs and CNRAs show that some of the indicators for HCVs are often assessed with specified risk. It means that additional documentation must be collected by the FCP, likely with support from upstream actors. Experiences in relation to legality verification systems, that communication and collaboration with suppliers in all steps of the due diligence implementation is fundamental to gain a close working relationship characterised by the trust, which also facilitates access to information in order to assess and mitigate risk (NEPCon 2018). This experience is confirmed by a wood pellet company in SE US, which had continuous communication with forest owners over several years, for example in connection with the SFI Fiber Sourcing program (J. Jenkins, personal communication). As of 2017, around 70% of the timber volume harvested in US is certified to SFI Fiber Sourcing standard, of which 94% came from private lands and 6% from public lands (SFI 2017). The groundwork for this achievement was laid even earlier, during decades of work with implementation of Best Management Practices (BMP) for water quality, biodiversity, and other forest practice requirements supporting SFM through logger training programs, and in the end, also certification. In this manner, the SFI have increased the share of fiber delivered to program participants by trained professionals from 34% in 1995 to 96% in 2016. Even if the approach used for Fiber Sourcing in some regards resembles other systems that do not require FMU level certification, and also involves auditing procedures, it is unique to the SFI. The approach has not been included among the verification approaches requested for any biomass category in the VP, and it is also not recognised by existing systems that endorse SFI certification, such as SBP or PEFC. However, it is well suited for the SE US, as it is based on land owners' voluntary participation.

Scenario 3 is probably not culturally feasible at a significantly larger scale in the SE US or in the Baltic countries; the cultural barriers seem surprisingly similar among small forest owners in those two regions, in spite of very different historical backgrounds. The work with implementation of BMPs, logger training and Fiber Sourcing certification have likely facilitated SBP certification, for which FCPs also rely on upstream actors' voluntary collaboration to mitigate specified risks, for the FCPs to obtain its SBP certificate. Several exporting pellet plants have as such been certified to the SBP (Table A4 of Annex A), indicating that a risk-based approach to documentation of SFM is feasible in SE US at the current scale of production. Considering previous experiences in the region, it may require some decades to expand the supply base to an even larger number of land owners, if it is possible at all. Several wood pellet plants are also certified to the SBP in the Latvia and Estonia, which both have an SBP-endorsed Regional Risk Assessment (RRA) in place, with plants having developed mitigation measures for indicators with specified risk (Table A7 of Annex A). The share of certified

forest area in the Baltic countries is considerable, but also connected to FSC and PEFC certification of large state forest areas, which constitute about 40, 50 and 60% of the forest area in Estonia, Latvia and Lithuania, respectively (Table 1, and see Table A2 of Annex A for more details). Also in this region, however, private forest owners are new and there is no long tradition for collaboration and communication among forest owners, and even less in the supply chain. Forest owner associations are being established for collaboration among owners, but there is only little evidence of real integrated management, equipment sharing or financial cooperation (Sarvasova et al. 2015). It will take time, as in SE US, to establish trustworthy working relationships with small forest owners in the Baltic countries.

Scenario 4 is not culturally feasible in SE US at all, and it will likely also be difficult to achieve for the Baltic countries. The impression from a wood pellet plant in SE US is that sawmills' resistance to certification and documentation of sustainability is now more economic than cultural (J. Jenkins, pers. comm.). This is no immediate reason to believe that this is different in the Baltic countries. Most industrial forest owners in SE US, and thus about one third of the private forest area (Table 1), have been certified to SFI SFM standard, comprising in total about 13.5 million ha, with about 1.6 million ha certified to the FSC SFM standard in this region. The corresponding numbers for the three Baltic countries together are about 2.9 and 3.6 million ha for PEFC and FSC, respectively, including double certification for some forests. Attitudes of non-industrial private forest owners (NIPF) towards certification in the US are a result of several other factors, such as life cycle (e.g., recreating on their wooded land, plans to transfer land in the next 5 years, retirement), cohort (e.g., education level, help with programs or policies), and period (e.g., wars, economic depressions changing attitudes or behaviors) (Butler et al. 2017). Creamer et al. (2012) found that non-timber objectives had negative marginal effects on awareness of forest certification programs. Consistent with this, Thompson and Hansen (2012) found that plans to harvest timber or bequeath to heirs, and educational level tended to have a positive influence attitudes of NIPF towards involvement in programs for forest carbon offsets (assuming that there is a parallel between forest certification and forest carbon offset programs). Moreover, studies also show that NIPF are generally unwilling to bear the cost (Perera 2007, for Louisiana and Mississippi, Creamer et al. 2012, for the US as a whole). Kilgore et al. (2007) thus conclude, for Minnesota, that forest certification among NIPFs is unlikely to expand substantially in the foreseeable future. As of 2012, only 0.2% of the forest land owned by NIPF in the US is enrolled in a forest certification system, even if private lands constitute 35% of the total US forest area (Creamer et al. 2012), and around 69% of the private forest area under productive management in in the SE US (SFI 2017). Another issue is that NIPF may not be inclined to entrust NGOs with the administration of forest certification schemes or state or federal governments, but rather prefer the administration to be in the hands of private forest land owner organizations, as found for Louisiana and Mississippi by Perera et al. (2007). In the Baltic countries, the amount of certified area is less a barrier to Scenario 4, compared to the USA. All state forest in the three Baltic countries is certified to FSC, and in Estonia and Latvia also to PEFC (Actiņš and Kore 2006, Ahas et al. 2006, Bekeris 2011, Lazdinis et al. 2009). Certification of these significant forest areas also enabled chain-of-custody certification to begin (Ahas et al. 2006). However, it will likely be more difficult to engage the remaining private actors compared to those that have already been certified. Very successful group certifications exist in Finland where more than 300,000 owners are certified under 13 so-called regional PEFC certificates, or in Sweden, where more than 15,000 owners are certified under eight group certificates. Such certificates are often administered by forest owner organizations and extension services. However, while forest owner organizations have a century-long history in the Nordic countries, a large number of forest owners in the Baltic countries have newly reclaimed or bought their lands, and these owners are often poorly organized, with limited motivation to join private forest owner associations. Forest owner associations in Hungary, the Czech Republic and Slovakia do, however, provide services for forest certification, but this is not the case in any of the Baltic countries, or Romania (Sarvasova et al. 2015) (see Table A2 and A3 in Annex A for more details). On the other hand, prescriptive forest legislation may potentially facilitate and significantly ease implementation and the acceptance of certification. A review of Lithuanian certification standards revealed only minor differences from Lithuanian legislation (UN 2002, Brukas et al. 2013), with legislation being most important to, for example, biodiversity conservation (Elbakidze et al. 2016). In Lithuania, the Forest Act to a large extent still relies upon forest management principles formed to conduct detailed prescriptive forest management in state

forest, as during the Soviet period (Brukas 2015). Even if this is less the case in Latvia and Estonia (Lazdinis et al. 2004), the regulatory approach still tends to be prescriptive, at least for some issues, compared to the Nordic countries (Ring et al. 2017; Nichiforel et al. 2018). Prospects are probably poor for getting small forest owners certified in the Baltic countries (V. Brukas, pers. comm.). Experiences from Romania indicate that changes towards more certified forest areas are incremental at a slow rate, and that it takes many years to make significant change (L. Nichiforel, pers. comm.).

It is difficult to separate the pure effects of attitude from the effect of economic profitability, but overall there must be a business case for certification, and, next, it is often necessary to work for several years with forest owners, wood processors, sawmills, and wood dealers, especially small scale actors, in order to develop trust and get them interested and involved. The time needed will depend on the region or country. Some proportion of small private non-industrial land owners will most likely never get certified (e.g. Kilgore et al. 2007).

Table 1. Forest area by ownership and forest certification scheme in the US, SE US and the three Baltic countries. Note that the certified area may sum to >100% due to double certification, and that the share of certified forest of the managed forest area might be significantly larger than the share of the certified forest of the total forest area. This is illustrated by 11% of the forest area being certified globally, while certified roundwood production is estimated to account for about 29% of the total global roundwood production (UN-ECE/FAO 2016). However, information about the managed proportion of the forest area or the certified proportion of the roundwood production is not available, except that 70% of the wood production in the US is certified according to the SFI Fiber Sourcing standard, and through this address the management on 94% of the private forest land and 6% of the state forest lands in the US.

Country /region	Forest area by ownership type				Total forest area	Certified forest area			
	Public	Private		Other		FSC	PEFC/SFI /ATFS	FSC	PEFC/SFI /ATFS
		Corporate	Non-corporate						
	1000 ha				1000 ha	1000 ha		% of total forest area	
US[f]	129,974	178,746		-	308,720	14,447[d]	33,498[c]	5	11
SE US[a]	9,672[b]	24,281[b]	46,539[b]	-	80,492[b]	1,641[e]	13,547[c]	2	17
Estonia	923[f]	1,038[f]		273[f]	2,234[f]	1,429[h]	1,174[g]	64	53
Latvia	1,755[f]	1,594[f]		-	3,349[f]	1,022[h]	1,701[g]	31	51
Lithuania	1,333[f]	837[f]		-	2,170[f]	1,124[h]	-[g]	52	-

[a]SE-US data for 12 southern states: Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, and Oklahoma.

[b]Source: Jeffries and Leslie (2017).

[c]SFI and ATFS are endorsed by PEFC and counts towards PEFC Global Statistics. Data for SFI are accurate as of September 6th, 2017 (25,911 x 1000 and 8,890 x 1000 for US and SE US, respectively, and data for ATFS are accurate as of March 21st, 2017 (7,587 x 1000 and 4,657 x 1000 ha for US and SE US, respectively).

[d]FSC data are accurate as of October 2016.

[e]As of September 6th, 2017, this is the most recent data available on FSC's website providing a by-state breakdown of certified area.

[f]FAO Global Forest Resource Assessment (2015). Forest areas are calculated from Table 45 of FAO (2015), Desk reference report, and FSC and PEFC certified areas are from Table 41 and 42, respectively.

[g]PEFC global statistics, by September 2017. https://www.pefc.org/images/documents/PEFC_Global_Certificates_-_Sep_2017.pdf

[h]FSC Facts and Figures, by December 2017. https://ic.fsc.org/en/facts-and-figures

6 Increased pressure on forests?

An analysis to identify possible pressures on forests from increasing wood pellet production in SE US was conducted by Dale et al. (2017). While not specific to secondary residues, the analysis focused on the same concerns as those expressed by Dutch NGOs. Together with another recent study by Jeffries and Leslie (2017), they identify, as the greatest risks to SE US forests, urban expansion and land development, lack of market demand for wood products, and increases in invasive species, fires, and other disturbances related to climate change. Jeffries and Leslie (2017) further show that, even with significant demands for forest products in SE US

since the early 1950s, there has been a net increase in forest land use and inventory of the quantity of resources available for harvesting and management (Jeffries and Leslie 2017). We suggest this indicates that the risk of a net deforestation in SE US landscapes due to wood pellet production is low. The land use patterns have, however, been dynamic during this period, and land use changes also involve forest land (Jeffries and Leslie, 2017). The total forest area in SE US is about 80.5 million ha or 199 million acres. Approximately 36 million acres of forestland were converted to other land uses in the 12 southeastern states between 1982 and 2012. Of this area, >50% were lost to development of urban areas, infrastructure, and other rural uses. The loss to development was more than the loss to any other land use type. The rest of the forest conversion was mainly driven by agricultural uses, such as pasture, crop or rangelands, but not by wood harvesting. Jeffries and Leslie (2017) suggests together with Dale et al. (2017) that actively managed forest prevents forest conversion to not only agriculture, but also urban land use, when the forest part of the estate is perceived as having a value. Active forest management means that activities are being planned and carried out in the forest in order to achieve the owner's forest management goals, cf. also section 5.

Old-growth and bottomland forests have been of specific concern in relation to protecting high conservation value nature and biological diversity. The review by Dale et al. (2017) showed that there are only few remnants of old-growth forests in SE US, that these are almost only found in areas that are protected, also from logging activities, soil preparation or fertilization. As for bottomland forests, many were converted to other land uses during the last two centuries or they have been managed for production of wood (Dale et al. 2017). Conservation programs have promoted the restoration of bottomland forests previously converted to other land uses, and regulations protect water and threatened and endangered species in these forests, and generally prevent forest management activities from converting wetlands to other land uses (Dale et al. 2017). Rather than forest management, the greatest threat to these forests are conversion to urban uses, anthropogenic alterations in flooding patterns, and high populations of white-tailed deer, that promote expansion of invasive species (Dale et al. 2017).

The conversion of natural forest to plantations is also a public concern in relation to nature values and biological diversity. Data show that forest cover conversion took place for about 10% of the timberland areas during the period 1989-1999 (Jeffries and Leslie 2017). The conversion of natural forest to plantations is almost equal to the area with plantations being converted to natural forest. While forest cover conversion from natural pine or natural oak/pine forest to planted oak/pine or pure pine or hardwood stands may reflect the owners' reactions to trends in the market, it could also be a sign that inferior forest types are being restored or improved, not only in terms of timber production, but also for conservation. For example, US conservation groups agree that commercial viability of longleaf pine, which is a IUCN-listed species, is crucial to its restoration (SBP 2016). However, the relationship between forest management and biological diversity is not simple. At stand level, some activities, including residue removal, will create habitat some species, while habitats for others might disappear (Demarais et al., 2017). Varied silvicultural practices in the landscape, such as multiple successional stages, and planning management to retain habitat elements, protect riparian zones, limit final harvest unit size and how soon adjacent forest patches can be harvested etc. may ensure habitat for a diversity of species, as Demarais et al. (2017) conclude for terrestrial vertebrate species.

Such management practices are supported by federal and state policies and programs such as the Endangered Species Act, state water quality laws, and forestry best management practices (BMPs) work to protect rare species, habitats and water quality (Dale et al. 2017). Furthermore, these efforts are endorsed and supported by forest certification (SFI 2017). High conservation values in managed forests, especially forests under industrial certified forest ownership, are well-defined and mapped, and current science-based BMPs detailing how to best protect these values in managed forests has received extensive attention (Dale et al. 2017). Additionally, various efforts in SE US are ongoing to advance this knowledge, including efforts by individual companies, SFI and its Implementation Committees and SBP working groups.

While SBP certification seems to create an incentive for developing documentation, and, perhaps, management in relation to indicators with specified risk, it is less likely that requiring SFM verification for secondary residues

bring additional benefits, or that it will create a loophole to get around SFM requirements for primary feedstocks. It is important to keep in mind that the magnitude of the traditional wood products and pulp and paper industries indicates they are larger economic players (97% of total harvest in metric tonnes in SE US) in the forested sector and supplying landscapes than wood pellet industries are. It must thus be expected that the traditional sectors drive trends in forest management strategies for a certain forest type, rather than wood pellet mills that are in whole or in part based on secondary industrial residues as feedstock (Dale et al., 2017). Hence, there is currently no evidence to suggest that south-wide forest degradation and deforestation has taken place in SE US, or that this will happen in the future as a result of wood pellet production (Dale et al., 2017).

There is also no evidence that a country-wide forest degradation and deforestation is taking place in the Baltic countries. The forest area is growing at varying rates (FAO, 2015, Table A8 in Annex A), and illegal logging has been reduced to such an extent that risk is normally considered to be low (SBP, 2017). The overall harvesting ratio, i.e. the ratio between timber harvest and stem increment, is 61% in Lithuania, with similar harvesting ratios in state and private forests (Brukas et al. 2011). It was assessed that the ratio could potentially be raised to 70-80%, and still adequately take environmental values into account (Brukas et al., 2011). Currently, however, such harvesting is inhibited by rigid legislation and planning routines that are supported in the forest political arena. The legislation in Estonia and Latvia is more liberal and harvesting ratio may be higher in these countries as indicated by values between 75 and 100% for the period 2000-2010 (Levers et al. 2014). In Estonia, the ratio in the same period apparently exceeds 100% in some parts of the country, but this can be explained by post-storm fellings in 2005.

In boreal Nordic and Baltic countries, the Woodland Key Habitats (WKH) is a key concept in biodiversity conservation. WKHs are defined as environments where red-listed, rare or specialist species occur, or are likely to occur. Conservation of WKHs is primarily based on forest legislation in Finland, Estonia and Latvia, and on forest certification in Sweden, Norway and Lithuania (Timonen 2010). In Estonia and Latvia, the principle is to exclude WKHs from forest harvesting activities (Timonen 2010). WKHs are also generally protected in FSC certified forests as HCV, even if critiques suggest for Lithuania that the legislation and use of evidence-based ecological knowledge is more effective for biodiversity conservation, compared to FSC certification and conservation of HCVs as currently practiced (Elbakidze et al. 2016). As indicator of the development in conditions for biological diversity, compulsory forest certification on all state enterprises in Lithuania, as well as the general trends in silvicultural activities, has led to an greater share of mixed species plantations, increasing from 32% in 1994 to 86% in 2008 (Brukas et al. 2011).

As in SE US, traditional wood products and pulp and paper industries are larger economic players, compared to wood pellet mills. For example, 87.5% of the value of forest exports comes from wood products in Latvia in 2014 (Fig. A3 of Annex A).

7 Discussion

Current experiences with sustainability certification of wood pellets are mainly for wood pellets produced in Europe and North America. These wood pellets are consumed domestically, or they are exported mainly for energy production in Member States in the EU, or in Asia. While pellets sold for household use are usually sold without certification claims, wood pellets for industrial use in EU Member States are usually sold with certification claims (Thrän et al. 2017).

This is mainly driven by national systems in UK and Denmark, which require sustainability documentation for wood used for bioenergy. The UK was an early mover when it adopted national requirements for solid biomass, biogas or bioliquids to generate electricity in 2009 under the Renewables Obligation (RO), with the introduced criteria being further developed in 2011 to require information on GHG emissions and land use (Mansoor et al., 2016). The criteria were adopted into national legislation in 2013 and became statutory in October 2015. FSC

and PEFC forest certification are recognized for showing compliance with the UK legislation, as so-called Category A evidence, while SBP is recognised as so-called Category B evidence (other evidence). The voluntary Danish Industry Agreement to ensure sustainable biomass was concluded in 2014, with a transitions phase from 2016 to 2019. For 2016, 2017 and 2018, 40%, 60% and 75% of the forest biomass used by the Danish energy utilities must be documented as sustainable (Dansk Energi og Dansk Fjernvarme 2016). In 2019, when the agreement is fully phased in, 90% of the biomass must be documented as sustainable, while legality documentation is required as a minimum for the remaining 10%.

Even if the SFM requirements under SDE+ include additional requirements compared to the UK legislation and the Danish agreement, experiences from the UK and Denmark might give an impression of the feasibility of implementing sustainability requirements under SDE+. An interview-based study from 2013 indicated the certified amounts of wood pellets imported to the Netherlands and the UK in 2010, but no solid statistics were available at that time, it is not known to which extent the certified pellets were based on primary or secondary feedstocks (Goh et al. 2013). The most common certification systems used included GGL[12], Laborelec Label and Drax Power Sustainability, with the latter two being abandoned when SBP emerged.

In the UK, the energy utility Drax is the largest bioenergy producer and wood pellet importer. Drax now reports its sustainability performance on its website (Drax, 2018). They inform that in 2016, 87% of the biomass used at Drax Power Station had a FSC and PEFC certification claim, up from 70% in 2015. Sawmill residues fibers constitute 40% of their feedstock supplies. Their main sourcing region in 2016 was the USA (60%), followed by Canada (22%).

The first reporting to the Danish agreement was made for the period 1 August - 31 December 2016. Eight reports from members of 'Dansk Energi', indicate that larger energy companies reached a share of sustainability documented forest biomass suppliers of about 60-70%, while medium size companies generally reached the required share of 40% (Dansk Energy 2017). The two largest companies predominantly used the FSC system as documentation, and, to some extent, PEFC. The major portion of the un-documented biomass for one of them was FSC CW and PEFC CS verified. Other companies used SBP certified biomass or other alternative sustainability documentation. Such alternative documentation included on-site third party auditing e.g. by use of a developed system developed by NEPCon for Danish conditions. In other cases, NEPCon's third party auditing verified that the biomass came from FSC or PEFC certified forests, however, with a 'broken' chain of custody. Sourcing regions included Denmark, Estonia, and Latvia. Two companies also sourced biomass in Russia during this period, and one also in Australia, Portugal, and the USA. The alternative documentation was mainly applied for domestic primary biomass, but also sometimes biomass from Estonia or Latvia.

These data indicate that certified markets for wood pellets are so far developing together with the demand, and that pellets purchased by large energy producers from distant regions more often come with FMU level SFM certificates (Drax 2018, Dansk Energy 2017). Data from Denmark also indicate that domestic biomass is more often SBP compliant, or use alternative documentation with third party auditing of selected suppliers, and selected criteria, probably those with specified risk. However, it is not clear with which rate the certified markets are developing, and as such also not how close they are to reaching their full sustainable potential.

It still worth noting, that the existing risk-based certification approaches, applied to wood pellets based on primary or secondary feedstocks, are positively encouraging definition and identification of high conservation values in managed forests in both SE US and the Baltic countries. Possibly, they also contribute to advancing

[12] GGL used to be a quick-scan assessment on sound forest management practices that was only valid for four years, after which full certification according to FSC and PEFC was required. At present, the GGL standard is seeking to align with the SDE+ requirements (ADBE 2018).

other SFM practices in these regions. Forest certification at FMU level since the 1990s is generally recognized as having improved forest management practices in the US, also in the uncertified proportion of the forests in the landscape, even if pronounced benefits are already being ascribed to the efforts with implementation of governmental best management practices (BMPs). Work has also been undertaken in the Baltic countries to identify and map high conservation values, as part of FSC and SBP certification, but most importantly, certification seem to have increased the general awareness, transparency and public involvement in the forest management. This may also prove to be important in the long term, in relation to sustainability documentation for the currently uncertified part of the forest area.

8 Conclusions

The objective of this report was first to analyze and assess the feasibility of tracking SFM certificates (FSC or equivalent) for secondary residue-based wood pellets used in Dutch energy production facilities, in a chain of custody from the forest management unit (FMU) to the energy production plant (EPP). While implementation of current requirements for secondary feedstock (point of origin, apart from greenhouse gas emission savings) are feasible during the transition period until 2020/2022, there is more doubt about the extent to which SFM requirements can be implemented, especially if FMU level verification is required. There might be some potential to advance both risk-based and FMU level certification and thus tracking certificates down the supply chain for secondary residues, but we only expect this to happen to a significant extent, if SFM certification requirements are introduced for lumber and wood products and pulp and paper. Perhaps introduction of strong financial incentives for energy end-use, which allows for substantial premium prices, could also help. However, a key factor to successful engagement for part of the non-industrial private forest owners (NIPF) seems to be development of good communication and trustful working relationships and improved organization of the owners to facilitate group certification. Experiences show that development of such communication and working relationships take time. However, the needed magnitude of the economic incentives is not known, and there is skepticism that it will help for the main part of the NIPF, especially in SE US (Table 2 and 3). The risk-based approach to verification of compliance with SFM is less demanding to forest owners and sawmills, compared to FMU level certification, and might hold more potential, especially in the long term.

We also aimed at assessing if not requiring FMU level SFM certification for secondary residues will result in an increased pressure on forests in sourcing regions. There is no evidence of wide-ranging deforestation and degradation in either SE US or the Baltic countries, or that it will be the case in the near future. Drivers of deforestation are mainly urban development, and not forest management activities, and the trend in the Baltic countries and SE US is a net increase in the forest area. This is especially the case for secondary residue-based products that mainly rely on the existing trends in forest management, driven by timber demands for end-uses that are economically more important to the forest owner than energy. This suggests that requiring verification of compliance with SFM criteria for secondary residues alone is not likely to have significant impact on forests or their management, meaning also that not much will be gained by requiring verification of SFM for secondary residues.

Table 2. Summary of the assessment of technical, economic and cultural feasibility of scenarios 2-4 for supply chains producing wood pellets from secondary feedstocks in SE US for end-use in the Netherlands, see also Fig. 4 and 5. Note that the table only includes what relates to SFM verification, not GHG verification. No SFM documentation is required in Scenario 1, corresponding to the current Dutch requirements for Category 5 biomass (cf. the Verification Protocol of the SDE+ program). Scenario 1 is likely feasible already by 2020-2022. Note that 'Required information' for scenario 2-4 refers to the certificates that move with the material through the chain of custody. It is assuming that certification systems for FMU level certification exist which have been approved for showing compliance with SDE+ SFM criteria.

Aggregation point	Feedstock received	Source of feedstock, possible aggregation	Number of links to FMU	Degree of difficulty in tracking documentation back to FMU	Required information Scenario 4	Required information Scenario 2-3	Probability of making change, Scenario 4 by 2020+	Probability of making change, Scenario 2 or 3 in SE-US by 2020+
Logger	Round-wood	Many forest owners, possibly from different states	0-1 (0 if the logger is also the owner)	Relatively easy	CoC for 100% FMU certificates	None or possibly documentation for risk mitigation measures	Not possible	No to low incentive for loggers. Will depend on forests owners' willingness to deliver information for possible risk mitigation
Wholesaler of roundwood (wood dealer)	Round-wood	Many forest owners, loggers and possibly other wholesalers	Up to 3	Easy to moderate to difficult	CoC for 100% FMU certificates	None or possibly documentation for risk mitigation measures	Not possible	No to low incentive for wholesalers. Will depend on forests owners' or loggers' willingness to deliver information for possible risk mitigation measures
Sawmill (PO)	Round-wood	Many forest owners, loggers and, possibly, wholesalers	Up to 4 or 5 (depending on aggregators along the chain)	Easy to difficult to very difficult	CoC for 100% FMU certificates	None or possibly documentation for risk mitigation measures	Not possible	No to low incentive for sawmills, but will in most cases depend on capacity, incentive to certify lumber sold, and upstream suppliers' willingness to supply information for possible risk mitigation
Secondary manufacturing plant (e.g. furniture, window frames) (PO)	Lumber, possibly sawdust and offcuts	Many sawmills, possibly in different states	4 or more (depending on aggregators along the chain)	Difficult to very difficult	CoC for 100% FMU certificates	None or possibly documentation for risk mitigation measures	Not possible	No to low incentive for manufactures, but will in most cases depend on incentive to certify wood products sold, and upstream suppliers' willingness to supply information for possible risk mitigation.
Secondary residue aggregator	Sawdust and offcuts	Many sawmills, secondary manufacturers, and, possibly, tertiary manufacturers	Up to 4 or more (depending on aggregators along the chain)	Very difficult to extremely difficult	CoC for 100% FMU certificates	CoC + 100% FCP certified to SFM standards, with verification by use of a risk-based approach	Not possible	High incentive due to sales opportunities, but will in most cases depend on upstream suppliers' willingness to supply information for possible risk mitigation
Pellet plant (FCP)	Sawdust and off cuts	Many sawmills, secondary and possibly tertiary manufacturers and possibly secondary residue aggregators	Up to 4 or more (depending on aggregators along the chain)	Very difficult to extremely difficult	CoC for 100% FMU certificates	CoC +100% FCP certified to SFM standards, with verification by use of risk-based approach	Not possible	High incentive due to exporting opportunities, but will in most cases depend on upstream suppliers' willingness to supply information for possible risk mitigation
Energy production plant (EPP)	Wood pellets	Many wood pellet plants in difference regions and countries.	Up to 7 or more	Very difficult to extremely difficult	CoC for 100% FMU certificates	CoC +100% FCP certified to SFM standards, with verification by use of risk-based approach	Not possible	High incentive due to subsidies, but will in most cases depend on upstream suppliers' willingness to supply information for possible risk mitigation.

Table 3. The authors' assessment of the feasibility of implementing SFM requirements under the four policy scenarios for wood pellet supply chains based on secondary feedstocks, by 2020 and the long term (a decade or more), in southeastern US (SE US) and the three Baltic countries, Estonia, Latvia and Lithuania (with some differences between these countries that are disregarded here). SFM: Sustainable Forest Management, FCP: First Collection Point, FMU: Forest Management Unit, RBA: Risk-based assessment.

No	SFM requirements	CoC requirements	SE US		Baltic countries	
			By 2020	Long-term	By 2020	Long-term
1	Point of origin	From FCP	****	*****	****	*****
2	Controlled	From FCP + RBA	**	***	****	*****
3	SFM	From FCP + RBA	**	***	***	****
4	SFM	From FMU	-	*	*	**

- (not feasible)

* (not likely that it is feasible, but also not completely excluded)

** (some small chance that it is feasible, but probably not at a scale that is far above today's use)

*** (feasible, but probably not at a scale that is far above today's use)

**** (feasible, also above today's scale of use)

***** (feasible, well-implemented in the whole country/region)

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Annex A – Additional Figures and Tables

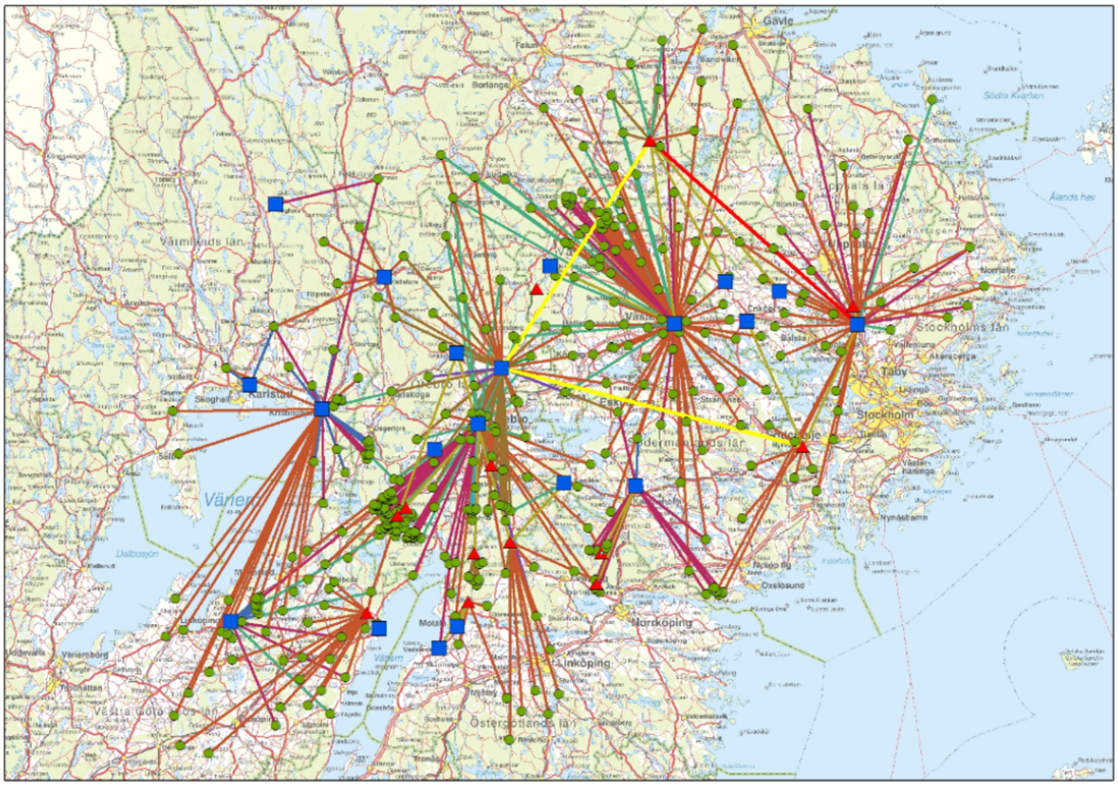

Figure A1. Map of optimized primary wood chip flows in Sweden, with red and yellow lines being train transportations; other colors are truck transportation of different assortments (Flisberg et al. 2010). Green dots are biomass suppliers (forests), red triangles are terminals (storage, chipping), and blue squares are customers (energy production plants).

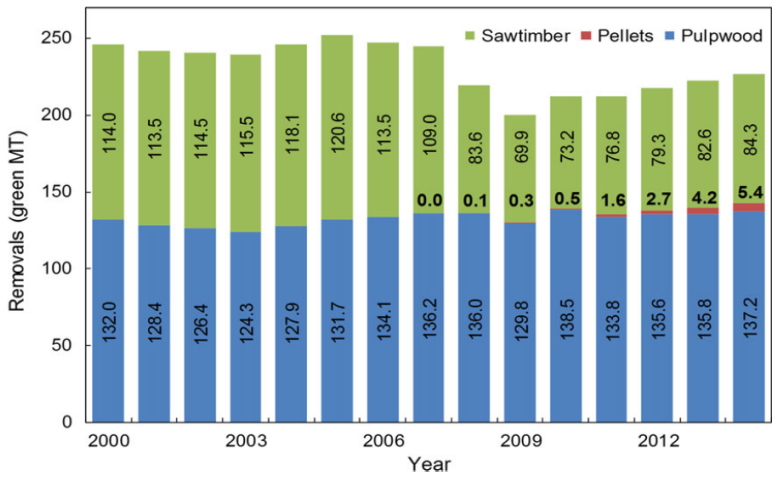

Figure A2. The share of the annual harvest used for wood pellets remains small in comparison to the wood used for sawtimber and pulpwood in southeastern US (from Dale et al. 2017, based on Forest2Market data reported for the Atlantic and Gulf regions (Stewart, 2015). MT: metric tonnes.

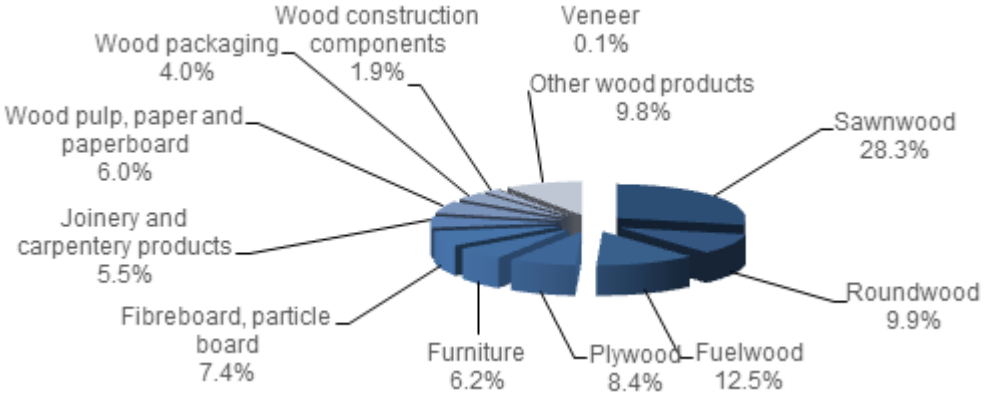

Figure A3. The distribution of wood export from Latvia across the economic value of different wood products in 2014 (LIAA, 2017).

Table A1. The four policy scenarios addressed in this report, including relevant existing certification systems for each scenario, of which some are approved by the Dutch Timber Procurement Assessment Committee (TPAC) as of 7 March 2018. Note that scenario 1, 2, 3 and 4, corresponds to current the Ducth SDE+ Verification Protocol sustainability and verification requirements for Category 5 biomass, Controlled biomass, Category 2 biomass and Category 1 biomass, respectively (Netherlands Enterprise Agency, 2017)[d].

No.	Policy scenario description		SFM governance		CoC governance
	SFM and non-controversial sourcing requirements and verification approach	Tracing requirements	Existing relevant systems for SFM[c]	Approved by TPAC for the Dutch requirements	Existing relevant systems for CoC = CoC approved by TPAC
1	Secondary feedstocks require verification of the point of origin, but do not require verification of standards for SFM or non-controversial sourcing.	CoC from the FCP to the EPP.	-	-	FSC CoC, PEFC CoC, SBP CoC, and GGL CoC
2	Secondary feedstocks require verification of low risk of non-compliance with standards for non-controversial sources [a].	CoC from FCP to the EPP.	EUTR, FSC CW, PEFC CS, SBP CF FSC SFM, PEFC SFM SBP SFM, GGL SFM	FSC CW, PEFC CS, FSC international, PEFC international, including MTCS	FSC CoC, PEFC CoC, SBP CoC, and GGL CoC
3	Secondary feedstocks require verified low risk of non-compliance with standards for SFM[b].	CoC from FCP to EPP	FSC SFM, PEFC SFM, SBP SFM, GGL SFM	FSC international, PEFC international, including MTCS	FSC CoC, PEFC CoC, SBP CoC, and GGL CoC
4	Secondary feedstocks require verification of SFM at the FMU level.	CoC from FMU to EPP.	FSC SFM, PEFC SFM	FSC international, PEFC international, including MTCS	FSC CoC, PEFC CoC, SBP CoC, and GGL CoC

[a]In practice this will be a mix of FMU level certified and risk-based verified SFM and controlled wood sources, when the material reaches the FCP as controlled wood.

[b]In practice this will be a mix of FMU level certified and risk-based verified SFM when the material reaches the FCP as SFM verified.

[c]These list are not exhaustive, but contain the most important systems, in terms of forest area. Various alternative systems are also sometimes used to verify SFM in relation to UK legislation (OFGEM, 2018) and the Danish Industry Agreement (Dansk Energi og Dansk Fjernvarme, 2016).

[d]Abbreviations: SFM: Sustainable Forest Management. CoC: Chain of Custody, FCP: First Collection Point, as defined by the VP. FMU: Forest Management Unit, EPP: Energy Production Plant, as defined by the VP. GHG: Greenhouse Gases. EUTR: The European Union Timber Regulation (EC, 2010). FSC: Forest Stewardship Council, PEFC: Programme for the Endorsement of Forest Certification, MTCS: Malaysian Timber Certification Scheme, SBP: Sustainable Biomass Program, GGL: Green Gold Label, FSC CW: FSC Controlled Wood, PEFC CS: PEFC Controlled Sources, SBP CF: SBP Controlled Feedstock. See also glossary for abbreviations (see also Annex A).

Table A2. Conclusions (in italics) and considerations and documentation used for the assessment of technical, economic and cultural feasibility in SE US and the three Baltic countries, Estonia, Latvia and Lithuania, under four different policy scenarios, as defined in Table A1 (and the main text). Abbreviations: SFM: Sustainable Forest Management. EUTR: The European Union Timber Regulation (EC 2010), DDS: Due Diligence System, FSC: Forest Stewardship Council, FSC CW: FSC Controlled Wood. FSC NRA: FSC National Risk Assessment (NRA) by the national FSC, developed by an FSC Network Partner, The FSC Regional Office when an FSC Network Partner is not able to conduct the NRA process, or FSC when neither an FSC Network Partner, nor FSC Regional Office are able to conduct the NRA process. FSC CNRA: FSC Centralized National Risk Assessment (NRA) by external experts, overseen by the FSC Policy Standards Unit, in cooperation with the national stakeholders. PEFC: Programme for the Endorsement of Forest Certification, PEFC CS: PEFC Controlled Sources, SBP: Sustainable Biomass Program. FCP: First Collection Point, PO: point of origin, EPP: Energy Production Plant, cf. the Dutch Verification Protocol of the SDE+ program (Netherlands Enterprise Agency, 2017).

No	Policy scenario description	Technical feasibility	Economic Feasibility	Cultural feasibility
1	Secondary feedstocks require verification of the point of origin, but do not require verification of standards for SFM or non-controversial sourcing.	Technically feasible. The leading wood pellet plants (FCPs) can already today the requirements. Auditing at the point of origin of the secondary feedstocks (PO), typically primary and secondary wood processors, is not required, but is typically confirmed as part of the auditing of the FCP. Outside Europe, the EUTR would require additional documentation on the claimed country of origin of the secondary feedstock and verification of low risk of non-compliance with any legal issues. Indicators assessed with specified risk by the EUTR DDS may require collection of additional documentation at any link in the supply chain, depending what is needed to demonstrate low risk. The country of origin is normally the first general level of the risk assessment to identify where further risk specification should be carried out in relation to EUTR (NEPCon 2017, NEPCon 2018). Note, however, that the EUTR implementation, penalties and enforcement measures vary widely among EU Member States (European Commission, 2016).	Economically feasible. No documentation costs upstream from the FCP is needed; this system has already been implemented for pellet mills outside EU exporting to The Netherlands and other EU Member States through the EUTR, even if not necessarily for pellet mills within the EU. Auditing upstream, from the FCP, is not needed. EUTR already cover additional legality issues for companies exporting to Europe.	Culturally feasible. FCPs are generally willing to supply information to the EPP, and are able to get the information they need from sawmills.
2	Secondary feedstocks require verification of low risk of non-compliance with standards for non-controversial	Possibly technically feasible by 2020. The greatest challenge is probably the physical separation between 'controlled biomass' and undocumented secondary feedstock. Achieving the scenario also requires that adequate amounts of controlled primary feedstock are available in the market, as secondary residues are a byproduct from processing of the primary feedstock. The availability of controlled biomass depends on FCP ability to satisfy laws, including EUTR, and FSC CW or PEFC CS, and, later,	Possibly economically feasible, but resources must be available upstream for possible physical separation of controlled secondary feedstock from undocumented feedstock, and enough controlled primary feedstock must be available.	Possibly culturally feasible at the current scale of use, and possibly also at a larger scale, depending the regional risk profile. EUTR is being applied to verify low risk of illegality for countries outside the EU exporting biomass to the EU. A full FSC NRA is expected to be available for the USA by mid-2018, and FSC CNRAs have

	sources	maybe additional criteria required by the VP for controlled biomass. A benchmark between the VP and FSC CW and PEFC CS is still to come and might reveal differences in requirements between these standards. EUTR also includes secondary feedstocks. Scenario 2 will likely become more technically feasible if whole jurisdictions are assessed as low risk in national FSC CW national risk assessments (FSC NRA, or FSC CNRA), which then establish that there is low risk that wood from the relevant country wood comes from controversial sources, according to the five FSC CW criteria. In this case, it would only be necessary to document the country of origin of the wood. For countries outside the EU, this is part of the obligations under EUTR, while biomass from EU Member States is not immediately subject to such requirement. The current use of FSC CW and PEFC CS by the wood pellet producers and traders may indicate how feasible scenario 2 is. As of 15 September 2017, there are, globally, 19 wood pellet businesses with an FSC FM/CoC certificate, and 1711 wood pellet businesses with a FSC CoC or CoC/CW certificate. The first number indicates that organizations owning the pellet plant also own forest, which makes it easier to control sustainability documentation associated with the primary feedstocks. For the second number, most of the FSC CoC certificates are combined with a controlled wood (CW) certificate, often more than 70% in a specific country (Table A3). Among SE US wood pellet plants exporting to Europe (Southern Environmental Law Center, 2017), most have an FSC CoC/CW certificate (Table A4). However, the number of FSC SFM and CoC/CW certificates does not directly give information on the amount of FSC CW compliant material that is available overall to the actors in the region, and thus also not about the potential to expand production based on FSC CW materials (noting that FSC SFM compliant material by definition is also being FSC CW compliant). The status of the FSC National Risk Assessments (NRA) or Centralized National Risk Assessments (CNRA) for CW may also be a useful indicator of the feasibility of scenario 2. NRAs or CNRAs have been approved for Belarus, Belgium, Bulgaria, Denmark, Estonia, India, Ireland, Lao, Latvia, Lithuania, Republic	EUTR has been implemented and will provide documentation of low risk of illegality for countries outside the EU, but not for low risk of violation of other indicators. Economic feasibility may to some extent depend on which indicators of the NRAs are assessed with low risk and specified. For indicators with specified risk, the documentation of low risk must be provided by the company getting FSC CoC/CW certified. The FSC NRA for the US has been approved for category 1 and 5 of the VP, but not for category 2, 3 and 4 (Table A5). It is expected that the whole NRA will enter public consultation in October-November 2017, with expected approval by the FSC Policy and Standards Director by mid-2018. Until the whole NRA process has been completed, FSC CW partly relies on the company-developed risk assessments for CW category 2, 3 and 4. FSC CNRAs have been approved for the Baltic countries, with specified risks for some indicators in all three countries (Table A5). Mitigation measures, and thus additional documentation for these indicators, must be provided by the individual FCP, typically the wood pellet plant.	been completed for the three Baltic countries (FSC 2018). Cultural feasibility will depend on the need to put in place mitigation measures, especially for non-industrial private forests landowners, which are often more suspicious of outsiders and influence by ENGOs, than larger corporate forest landowners.

		of Korea, Romania, Slovakia, Ukraine and Vietnam. For several other countries, the final approval is expected to take place in 2018. In the US, FSC CW criteria 1 (avoiding illegal logging) and 5 (avoiding genetically modified organisms, GMOs) have been approved as low risk, while the assessment of other criteria is expected to be finalised by mid-2018 (FSC 2018). Most countries have some criteria assessed with specified risks for which additional documentation must be collected to show that the CW criteria are not violated. The collection of this documentation may also involve upstream actors, and it will likely vary from country to country and region to region how feasible it is to get this additional documentation (Table A5). Current experiences, e.g. in the US and Romania, indicate that due to constraints in economic and cultural feasibility, it is a slow, incremental process to create a trustful relationship with different actors. This is often a prerequisite for collection of documentation of low risk for indicators with specified risk.	No national or centralised national risk assessment process exists for PEFC CS, which instead relies on the company-developed risk assessments, through the PEFC CoC DDS. The FSC NRAs or CNRAs might cover most or all of the requirements by PEFC CS, but the PEFC system does not per se have a low cost alternative pathway to assess risks associated with PEFC CS.	
3	Secondary feedstocks require verified low risk of non-compliance with standards for SFM.	Scenario 3 may be technically feasible, but a challenge in the upstream part of the supply chain is again the physical separation between SFM compliant/controlled secondary feedstock and undocumented secondary feedstock. Only controlled feedstock can be mixed with SFM compliant material, not undocumented feedstock. It furthermore requires that adequate amounts of compliant and controlled primary feedstocks from risk-based certification systems become available, as secondary residues is a by-product from their processing, with no subsidy schemes requiring compliance with controlled wood for other wood end-uses than energy. Feasibility would also depend on ability of FCP to satisfy VP SFM requirements through a risk-based approach. Yet, no existing risk-based certification systems have been approved for showing compliance with the Dutch criteria for category 2 biomass. Once systems have been approved, the availability of compliant/controlled feedstock will depend on FCP ability to satisfy systems using risk-based approaches to verify compliance with SFM requirements. A benchmark between the VP and systems such as the SBP and GGL revealed differences in	Scenario 3 is economically feasible from the FCP and downstream, and possibly economically feasible for upstream actors at the current scale of exports from SE US and Baltic countries. Scenario 3 is maybe also economically feasible at larger scales, but resources must be available for possibly needed physical separation of compliant/controlled secondary feedstock from undocumented feedstock, and enough compliant/controlled primary feedstock must be available for processing into lumber, wood products and associated residues. A main technical and economic barrier to implementation is likely	Probably not culturally feasible at a significantly larger scale in the SE US, but with time, maybe in the Baltic countries, even if the cultural barriers seem surprisingly similar among small forest owners in those two regions, in spite of very different historical backgrounds. Leading wood pellet plants in the SE US or the Baltic countries no longer encounter significant pushback to develop profitable production. This new and favourable situation was probably possible due to a decade-long of work with forest owners and loggers, for example through the SFI Fiber Sourcing standard. Apart from work by SFI FS program participants, 34 SFI Implementation Committees (SIC) work at state, provincial and regional levels to broaden the practice of sustainable

		requirements. However, time and willingness are still needed for schemes to align, and for relevant actors to get involved, cf. economic and cultural feasibility. The current degree to which SBP is applied may indicate how feasible scenario 3 is, also for secondary residues. As of 15 September 2017, there are 100 organizations certified to SBP in several countries in Europe and North America (Table A4). Of these, 40 organizations are certified with a Supply Base Evaluation (SBE) and 60 organizations without a SBE, meaning that they only used material which already carries the needed documentation in the CoC. The SBE uses a risk-based approach to verification of the SFM requirements of the SBP standard. A SBE is not required if feedstocks already fulfil certain requirements, for example if they are already certified to SBP or another system that is within the scope of the SBP. As such, companies certified without a SBE will hold FSC CW or CoC, or PEFC CS or CoC certificates. The SBP SBE assessments sometimes take a starting point in already conducted work with the FSC CW NRAs or CNRAs, when it exists (SBP 2017). The FSC CW NRAs and CNRAs also use a risk-based approach to verification of compliance with CW criteria, which are included in the FSC SFM standard and overlaps with the SFM standard of SBP. As for FSC CW NRAs and CNRAs, most of the conducted SBEs have some criteria assessed with specified risk, for which additional documentation must be collected to show low risk of non-compliance with the specific SFM criteria. The collection of this documentation may again involve upstream actors, and, as for FSC CW, it will likely vary from country to country and region to region how feasible it is to get this additional documentation. SBEs have in some cases been conducted for whole jurisdictions. Denmark, Estonia, Latvia, and Lithuania have approved SBEs, also with specified risk for some indicators (Table A6). Examples of company-based SBEs in SE US are five approved SBEs for Enviva wood pellets plants (Table A6). Most pellets sold in Europe from SE US and the Baltic countries will be SBP certified (Table A5). Another indication of the feasibility of Scenario 3 may be that	to occur if flows of lumber and wood products have not already been separated in the same manner as required for secondary feedstocks. This approach of Scenario 3 is, however, currently being used by leading wood pellet plants (FCPs) in SE US and the Baltic countries, who for example apply the SBP system. In the SE US, implementation relies on company-developed supply base risk assessment for the individual plants, meaning that several risk assessments exist within the same company (Table A6). Regional Risk Assessments (RRA) have been completed for the three Baltic countries (Table A6), which means that companies in these countries generally do not need to pay to have a supply base evaluation carried out; they can and must use the national RRA. If some RRA or SBE indicators are assessed with specified risk, as is currently the case for the SBP SFM risk assessments, both in SE US and Baltic countries, additional documentation is needed from suppliers of secondary residues. SBP has been successfully implemented especially for wood pellet plants in the Baltic countries, also for secondary feedstocks. It seems the success is due to persistent efforts in	forestry through public outreach and education. The SICs involve a broad range of actors, including private landowners, independent loggers, forestry professionals, indigenous people, local government agencies, academics, scientists, and conservationists. Current experience in the SE US indicates that increasing the amount of SFM compliant biomass, through SFI's Fiber Sourcing approach or SBP's risk-based approach, would be a slow, incremental process. It takes time to build confidence and persuade upstream actors to get involved, change practices, and put systems in place for provisioning of documentation of such change. In the SE US, especially, it seems unlikely that sawmills and secondary manufacturer will generally become compliant with the required auditing in a wider scale. In the Baltic countries, the process of implementing SBP certification has also been a slow, incremental process. Increasing the certified amounts of biomass may increasingly encounter challenges that are economic and/or cultural in nature.

		70% of the procured wood harvest in the US is certified to the SFI Fiber Sourcing (SFI FS) standard. This is a standard for organizations that do not own or manage land but procure wood directly from forests, such as saw mills; forest management is addressed by these procurement actors working actively with the forest owners and especially loggers harvesting as much as 94% of the harvested private forest land and 6% of the state forest lands in the US. Cumulatively since 1995, more than 180,000 loggers (>10,000 in 2016) have participated in training to ensure that they understand how to minimise impacts of the harvesting on water quality, biodiversity and other sustainable forest management requirements. This means that 96% of all fiber supplied to SFI FS program participants in 2016 was delivered by trained professionals, as compared to 34% in 1995. Loggers who received training are more likely to implement BMPs during harvesting operations on, for example, nonindustrial private forests (Dale et al. 2017). As good collaboration and education in the supply chain is needed to acquire documentation to mitigate specified risks, SFI Fiber Sourcing may have created a solid foundation for making Scenario 3 in North America. SFI Fiber sourcing does not require a risk assessment of the supply base, but the certified organisation works directly with forest owners, loggers and other stakeholders, for example, through the 34 SFI Implementation Committees (SIC). Currently, it is not clear how such efforts might be directly recognized by those assessing if there is low or specified risk of non-compliance with SFM criteria.	setting up mitigation measures, and that this has been possible based on close contact to suppliers, sometimes achieved through long-term efforts to build up the relationship. They are thus able to acquire specific supplier information for each consignment, and suppliers having agreed to second party auditing, for example four times per year, and third party auditing, usually once per year (Mihkel Jugaste, pers. comm.). There are also examples of successful implementation of the SBP system in SE US, indicating economic feasibility for production at the current scale of exports.	
4	Secondary feedstocks require verification of SFM at the FMU level.	May be technically feasible, but not by 2020, as economic and cultural barriers are rather significant in the upstream part of the supply chain. It requires physical separation of compliant/controlled secondary feedstock from undocumented feedstock, and that enough compliant/controlled primary feedstock is available. In the end, feasibility depends especially on the economic incentives and overcoming the cultural barriers, from the FMU level to the FCP, see other columns of this table. As mentioned under Scenario 2, there are, globally, 19 wood	Scenario 4 is economically feasible from the FCP and downstream, but not for upstream actors by 2020 or 2022, even if it may be possible to make progress in a long term if direct or indirect financial incentives motivating forest owners, loggers, sawmills and secondary manufacturers are adequately high.	Not culturally feasible in SE US at all, , and it will likely also be difficult to achieve for the Baltic countries. There is no or very little chance to get 100% SFM certified FMUs in SE US. If it, against all odds, should become possible to increase the percentage of FMU certified land significantly in longer timeframes of decades, this will need to be driven by increased demands for

		pellet businesses that hold an FSC FM/CoC certificate, with 11 of these being located in Canada, and none in the US (Table A3). The scopes of the certificates have not been examined further, but the organizations holding them might be actors that own both forests and wood pellet mills. It is not known to which extent the production is based on primary feedstocks or secondary residues. If pellets are sold with an FSC or PEFC claim, it is likely that these are made from primary feedstocks, or a simple supply chain with sawmills that only take material from FSC or PEFC certified forests, as no physical separation would then be required for secondary residues. The amount of SFM certified forest is another indicator. Only a minor part of the wood harvested especially in SE US is from SFM certified forests (Table 1, see main text). However, it should be kept in mind that not all forests are actively managed and harvested. This means a larger proportion of the harvested wood will typically be certified, compared to the proportion of the forest area that is certified. Globally, around 29% of the harvested wood comes from certified forests, while only around 11% of the forest area is certified (UNECE/FAO 2017). Theoretically, the same percentage of secondary residues would be certified globally, but volumes of secondary feedstocks are rarely controlled throughout the supply chain.	Depends on financial incentives motivating forest owners, loggers, sawmills and secondary manufacturers, or possibly, SFM requirements in traditional forest product markets, or significance of markets for uncertified products. Only little synergy exists with the physically and economically far larger traditional forest product markets, where the demand for certified products is limited, especially in the SE US, and for which no EU, US or EU Member State SFM requirements exist beyond the EUTR or the Lacey Act (conservation law prohibiting trade with species that have been illegally taken, possessed, transported, or sold). The business case does not exist today for all the first-mentioned actors, especially not for secondary residues, but a theoretical tipping point is plausible, if economic incentives are introduced (Qian and McDow 2013), and/or if SFM requirements and associated CoCs are introduced for the traditional forest products industry. SFM requirements for the traditional industry seems more likely to happen than financial incentives, even if there are cases of tax exemption for certified land, e.g. in Romania (Liviu Nichiforel, pers. comm.)	certified lumber and wood products. Experiences show that many years of education and work with saw mills, loggers, and forest owners is needed to overcome mistrust associated with providing business data and forest owners' unwillingness to let others influence their forest management. Feasibility thus depends on pellet mills' willingness to comprehensively engage with sawmills, secondary manufacturer and forest owners, and their willingness to become certified (assuming financial incentives are adequate) in order to sell into an EU wood pellet market, since other existing traditional forest products markets do not require FMU certification. Small private forest owners in SE US are unlikely to get certified at all, and even more so as long as there are no SFM requirements for traditional forest products. In Estonia, Latvia, Lithuania, about 50% of the forest area, including all state forest, is already certified to FSC or PEFC (Table 1, see main text). In all Baltic states there were highly prescriptive top-down regulations during Soviet times, and especially Lithuanian legislation is still very prescriptive (Brukas 2015). A large number of forest owners have newly reclaimed or bought their lands, and a significant barrier to increasing the certified share of the forest area is probably poor organization of these owners. Also, owner goals other than delivering wood to the markets may be an important factor. In other countries

			While the forest area certified at FMU level is relatively small in SE US, at least 50% of the forest area is certified in Estonia, Latvia and Lithuania, depending on the degree of double certification (Table 1, see main text).	such as Sweden and Finland, group certificates are often administered by private forest owner associations, but forest certification is rarely among the services provided by private forest owner associations in Central and Eastern Europe and there is limited motivation of owners in these countries to join associations (Sarvasova et al. 2015).

Table A3. Number and types of SBP and FSC certificates for wood pellet producers or traders in different countries, as of 15 September 2017 (FSC 2017, SBP 2017).

Region	Country/state	SBP					FSC				
		BP with SBE	BP without SBE	Trader	Total operators for the country	Total operators for the region	FSC FM	FSC CW	FSC CoC	Total FM and CW for the country	Total operators for the region
Baltics	Estonia	6	2	-	8		-	37	11	37	
	Latvia	9	5	-	14		-	84	7	84	
	Lithuania	-	2	1	2	24	-	14	12	14	135
Canada	Canada	2	4	0	6	6	11	13	2	24	24
Europe	Belarus	-	16	-	16		4	11	31	15	
	Belgium	-	-	-	-		-	82	2	82	
	Denmark	6	3	6	9		-	14	3	14	
	France	-	-	-	-		-	7	2	9	
	Germany	-	-	1	1		-	95	55	95	
	Italy	-	-	-	-		-	4	21	4	
	Netherlands	-	-	2	-		-	194	2	194	
	Norway	-	1	-	1		-	2	-	2	
	Poland	-	2	-	2		-	16	73	16	
	Sweden	-	1	-	1		-	70	1	70	
	Ukraine	-	-	-	-		2	1	18	1	
	UK	-	1	3	1	30	-	82	33	80	606
Iberia	Portugal	-	8	1	8		-	34	0	34	
	Spain	-	1	-	1	9	-	6	2	6	40
Russia	Russia	-	14	1	14	14	1	47	39	48	48
USA	Alabama (AL)	1	-	-	1						
	Arkansas (AR)	1	-	-	1						
	Florida (FL)	1									
	Georgia (GA)	9	-	-	9						
	North Carolina (NC)	3									
	South Carolina (SC)	1	-	-	1	17	0	48	2	50	50
	Virginia (VA)	1									
Sum		40	60	15	100	100	18	861	316	1162	1162

Table A4. Sustainability certificates held by wood pellet plants in the US exporting to Europe (Southern Environmental Law Center 2017, certificate databases of FSC 2017, PEFC 2017, SFI 2017, SBP 2017, and company websites). It is not known how much SFM certified material flows into the FSC, PEFC, SFI and SBP CoC. However, rules require that max. 30% is CW/CS.

Wood pellet plants exporting to Europe		Export to the EU	SBP	FSC-CoC	FSC CW	PEFC-CoC	SFI-CoC	SFI-FS
1	Carolina Pacific Briquetting Co, Georgetown SC	x	-	-	-	-	-	-
2	Colombo Wood Pellets, Greenwood SC	x	x	x	x	x	-	x
3	Drax-Amite BioEnergy Drax Biomass, Baton Rouge Gloster MS	x	x	x	x	x	x	x
4	Drax-La Salle, Baton Rouge Urania LA	x	-	-	-	-	-	-
5	Drax-Morehouse BioEnergy Drax Biomass, Baton Rouge Bastrop LA	x	x	x	x	-	-	-
6	ENVIVA, LP (ports)	x	x	-	-	-	-	-
7	Enviva Pellets Ahoskie, Chesapeake Ahoskie NC	x	x	x	x	x	x	x
8	Enviva Pellets Amory, Mobile Amory MS	x	-	x	x	x	x	x
9	Enviva Pellets Cottondale, Panama City Cottondale FL	x	x	-	-	-	-	-
10	Enviva Pellets Northampton, Chesapeake Garysburg NC	x	x	x	x	x	x	x
11	Enviva Pellets Sampson, Wilmington Faison NC	x	x	x	x	x	x	x
12	Enviva Pellets Southhampton, Chesapeake Franklin VA	x	x	x	x	x	x	x
13	Enviva Pellets Perkinston, Mobile Perkinston MS	x	-	-	-	-	-	-
14	E-Pellets-Nahunta Nahunta Wood Pellets, Brunswick Nahunta GA	x	-	-	-	-	-	-
15	FRAM-ACP Appling County Pellets, Brunswick Baxley GA	x	x	x	x	x	-	-
16	FRAM-HWP Hazlehurst Wood Pellets, Brunswick Hazlehurst GA	x	x	x	x	x	-	-
17	FRAM-TFP Telfair Forest Products, Brunswick Lumber City GA	x	x	x	x	x	-	-
18	Georgia Biomass, Savannah Waycross GA	x	x	x	x	x	x	x
19	Lee Energy Solutions Plant, South Louisiana Crossville AL	x	x	x	x	-	-	-
20	Jasper Northeast Wood Products, Mobile Jasper TN	x	-	-	-	-	-	-
21	Westervelt Energy, Mobile Aliceville AL	x	x	x	x	-	x	x
22	Zilkha Biomass Energy, Mobile Selma AL	x	-	(x)	(x)	x	-	x
23	LJR Forest Products, Swainsboro, GA	x	x	x	x	-	-	-
24	Highland Pellets, LLC, Pine Bluff, AR	x	x	x	x	-	-	-
25	Varn Wood Products, LLC, Hoboken, GA	x	x	-	-	x	-	x
26	Solvay Biomass Energy, LLC, Quitman, MS	(x)	-	x	x	x	x	x

Table A5. FSC CW indicators as currently assessed to risk categories in the national risk assessments for various countries, either final or preliminary assessments (FSC 2018). 1.6: Value added taxes and other sales taxes, 1.7: Income and profit taxes, 1.11: Health and safety, 1.12: Legal employment, 1.21: Legislation requiring due diligence care procedures. An indicator is assessed with low or specified risk, based on the existing legislation in the country and on other relevant rules, practices and information.

FSC CW indicator	Issue	Estonia	Lithuania	Latvia	Denmark	Portugal	USA	Canada	Russia
		Final	Final	Final	Final	Draft	Draft	Draft	Draft
1.1-21	Avoid illegally harvested wood	Low risk	1.11, 1.21	1.6, 1.7, 1.11, 1.12, 1.21	Low risk	Low risk	Low risk	Low risk	Several specified risks
2.1	Avoid wood harvested in violation of traditional and human rights	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	
2.2		Specified risk	Low risk	Specified risk	Low risk	Low risk	Specified risk	Low risk	Specified risk
2.3		Low risk	Low risk	Specified risk	Low risk	Low risk	Specified risk	Low and specified risk	Specified risk
3.0	Avoid wood harvested where HCVs are threatened by management activities	Low risk	Low risk	Low risk	Low risk	Low risk	Not assessed	Low risk	Low risk
3.1		Low risk	Low risk	Low and specified risk	Low and specified risk	Low risk	Not assessed	Low and specified risk	Specified risk
3.2		Low risk	Low risk	Low risk	Low risk	Low risk	Not assessed	Low and specified risk	Low and specified risk
3.3		Specified risk	Specified risk	Low and specified risk	Low and specified risk	Low risk	Not assessed	Low and specified risk	Specified risk
3.4		Low risk	Low risk	Low risk	Low risk	Low risk	Not assessed	Low and specified risk	Specified risk
3.5		Low risk	Low risk	Low risk	Low risk	Low risk	Not assessed	Low and specified risk	Specified risk
3.6		Specified risk	Low risk	Low and specified risk	Low risk	Low risk	Not assessed	Low risk	Specified risk
4.1	Avoid wood from forests converted to plantations or non-forest use	Low risk	Low risk	Low risk	Low risk	Low risk	Not assessed	Low and specified risk	Low risk
5.1	Avoid wood from GMO trees	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Table A6. SBP indicators currently categorized with specified risk in the SBP regional risk assessments (RRA) for the Baltic countries states and Denmark and in the supply Base Evaluations (SBE) of plants owned by Enviva in SE US, and for which mitigation measures are needed (SBP 2017). An indicator is assessed with low or specified risk, based on the existing legislation in the country and on other relevant rules, practices and information. The individual biomass producer (BP, SBP terminology, typically a wood pellet or wood chip supplier) is responsible that mitigation measures are carried out to provide evidence of compliance. Examples show that the evidence may sometimes be requested from upstream actors, such as saw mills, loggers or forest owners, and that the BP is required to conduct regular audits of the relevant upstream actors, for example four times per year, while a third party (the certifying organization) carries out audits of the BP and selected upstream actors once per year (Mihkel Jugaste, pers. comm.).

SBP indicator	Estonia	Lithuania	Latvia	Denmark	Enviva Southampton	Enviva Cottondale	Enviva Sampson	Enviva Ahoskie	Enviva Northampton
	Endorsed	Endorsed	Draft	Endorsed	Endorsed	Endorsed	Endorsed	Endorsed	Endorsed
2.1.1. Control systems and procedures for verifying that hcv areas are identified and mapped	Low risk	Low risk	Specified risk	Specified risk	Specified risk	Low risk	Specified risk	Specified risk	Specified risk
2.1.2. Control systems and procedures to identify and address potential threats to hcv areas from forest management activities	Specified risk	Specified risk	Specified risk	Specified risk	Specified risk	Low risk	Specified risk	Specified risk	Specified risk
2.2.3. Control systems and procedures to ensure that key ecosystems and habitats are conserved or set aside in their natural state	Low risk	Low risk	Low risk	Specified risk	Specified risk	Low risk	Specified risk	Specified risk	Specified risk
2.2.4. Control systems and procedures to ensure that biodiversity is protected	Low risk	Low risk	Low risk	Specified risk	Specified risk	Specified risk	Specified risk	Specified risk	Specified risk
2.8.1. Control systems and procedures for verifying that appropriate safeguards are put in place to protect the health and safety of forest workers	Low risk	Specified risk	Specified risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Table A8. Forest area increase from 1990 to 2015 (1000 ha) (FAO 2015).

Country	1990	2015	Change (1990-2015)
USA	302,450	310,095	7645 (3%)
Estonia	2,206	2,232	26 (1%)
Latvia	3,173	3,356	183 (6%)
Lithuania	1,945	2,180	235 (12%)
Average, Baltic countries	7,324	7,768	444 (6%)

Annex B - Abbreviations

Abbreviation	Definition	Origin	Reference
ATFS	American Tree Farm System	Certification system endorsed by PEFC	https://www.treefarmsystem.org/
BMP	Best Management Practices	General terminology	
BP	Biomass Producer	VP and SBP terminology	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf https://sbp-cert.org/docs/2015-03/sbp-glossary-of-terms-and-definitions-v1-0.pdf
CNRA	Centralised National Risk Assessment	FSC terminology	https://ic.fsc.org/en/what-is-fsc-certification/controlled-wood/risk-assessments
CoC	Chain of Custody	General terminology, trail of documents	
CS	Controlled Sources	Associated with PEFC CoC	https://www.pefc.org/standards/chain-of-custody
CW	Controlled Wood	Associated with FSC CoC	https://ic.fsc.org/en/what-is-fsc-certification/controlled-wood
DDS	Due Diligence System	Assoicated with EUTR	http://ec.europa.eu/environment/forests/timber_regulation.htm
EPP	Energy Production Plant	VP terminology	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf
EUTR	European Union Timber Regulation	EU Directive	http://ec.europa.eu/environment/forests/timber_regulation.htm
FAO	Food and Agriculture Organization of the United Nations	UN organisation	http://www.fao.org/home/en/
FCP	First Collection Point	VP terminology	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf
FM	Forest Management	General terminology	
FMU	Forest Management Unit	VP terminology	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf
FS	Fiber Sourcing	SFI terminology	http://www.sfiprogram.org/sfi-standards/fiber-sourcing-standard/
FSC	Forest Stewardship Council	Forest certification system	https://www.fsc.org/

GGL	Green Gold Label	Certification system for sustainable biomass	http://www.greengoldcertified.org/
GHG	Greenhouse Gases	General terminology	
GMO	Genetically Modified Organisms	General terminology	
HCV	High Conservation Value	FSC terminology	https://ic.fsc.org/en/what-is-fsc/what-we-do/strengthening-standards/high-conservation-values
iLUC	Indirect Land Use Change	General terminology	
ISCC	International Sustainability and Carbon Certification	Certification system for sustainable biomass	https://www.iscc-system.org/
IUCN	International Union for Conservation of Nature	Membership union for protection of biodiversity, elaboration of red list species lists	https://www.iucn.org/
Lacey Act			https://www.fws.gov/international/laws-treaties-agreements/us-conservation-laws/lacey-act.html
MB	Mass Balance	SBP terminology	https://sbp-cert.org/docs/2015-03/sbp-glossary-of-terms-and-definitions-v1-0.pdf
MT	Metric Tonnes	US unit terminology	
MTCS	Malaysian Timber Certification System	Certification system endorsed by PEFC	https://mtcc.com.my/
NGO	Non-Governmental Organization	General terminology	
NIPF	Non-industrial Private Forest Owners	General terminology	
NRA	National Risk Assessment	FSC terminology	https://ic.fsc.org/en/what-is-fsc-certification/controlled-wood/risk-assessments
NTA 8080	Nederlandse Technische Afspraak 8080	Dutch standard	http://ecp-biomass.eu/node/42
PEFC	Program for the Endorsement of Forest Certification	Forest certification program	https://www.pefc.org/
PO	Points of Origin	VP terminology	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf

RRA	Regional Risk Assessment	SBP terminology	https://sbp-cert.org/docs/2015-03/sbp-glossary-of-terms-and-definitions-v1-0.pdf
SBE	Supply Base Evaluation	SBP terminology	https://sbp-cert.org/docs/2015-03/sbp-glossary-of-terms-and-definitions-v1-0.pdf
SBP	Sustainable Biomass Program	Certification system for BPs	https://sbp-cert.org/
SDE+	Stimulering Duurzame Energieproductie (Stimulation of Sustainable Energy Production)	Subsidy program for EPPs	https://www.rvo.nl/subsidies-regelingen/stimulering-duurzame-energieproductie-sde
SE US	Southeastern United States	General terminology	
SFI	Sustainable Forestry Initiative	Certification system endorsed by PEFC	http://www.sfiprogram.org/
SFM	Sustainable Forest Management	General terminology	
TPAC	Timber Procurement Assessment Committee	Dutch authority	http://www.tpac.smk.nl/32/home.html
UNECE	United Nations Economic Commission for Europe	UN organisation	https://www.unece.org/info/ece-homepage.html
VP	Verification Protocol	Valid for SDE+	https://english.rvo.nl/sites/default/files/2017/06/Verification%20Protocol%20for%20Sustainable%20Solid%20Biomass%20SDE.pdf
WHK	Woodland Key Habitats	Nordic and Baltic terminology	

IEA Bioenergy

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

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