Review

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Toward a harmonization of national sustainability requirements and criteria for solid biomass

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Abstract: This paper compares national sustainability support schemes and sustainability requirements in four countries that import solid biomass for heat and power generation: Belgium, Denmark, the UK, and the Netherlands. The paper also reviews voluntary certification schemes for solid biomass that may be used to demonstrate sustainability compliance. In the absence of mandatory EU criteria for solid biomass, different national support schemes and sustainability requirements may present barriers to trade. This paper identifies some possibilities for harmonization and provides suggestions for policymakers for the improvement and alignment of national sustainability requirements. Ultimately the paper suggests establishing a harmonized certification scheme in the short term based on legislative requirements in the four countries and in voluntary initiatives. The proposed harmonized certification scheme may also reduce both implementation costs and complexity for biomass suppliers and generators. In the long term, the paper recommends binding criteria on sustainability requirements for solid biomass at EU level. © 2017 The Authors. *Biofuels, Bioproducts and Biorefining* published by Society of Chemical Industry and John Wiley & Sons, Ltd

Supporting information may be found in the online version of this article.

Keywords: solid biomass; sustainability criteria; sustainability requirements; national support schemes; voluntary schemes; sustainable forest management; greenhouse gas emissions

Introduction

Renewable energy plays an important role in the European energy sector as it reduces the dependence of the European Union (EU) on fossil fuels and mitigates climate change.[1] In 2009, the European Commission (EC) issued the Renewable Energy Directive (RED)[2] in which member states set targets for the share of energy from renewable sources in gross final energy consumption by 2020. To ensure the sustainability of liquid biofuels (one type of bioenergy) used in the transport sector, the RED established sustainability criteria irrespective of whether the feedstocks are cultivated inside or outside the EU territory. Solid biomass, largely sourced from processing and harvesting residues, is also used to produce bioenergy (mainly for electricity, heating, and cooling) and is consid-

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ered as a potential source of renewable energy as well as a way to achieve greenhouse gas (GHG) emission reduction.* Solid biomass is the biggest source of renewable energy in the EU and is expected to make a key contribution to the 20% EU renewable energy target by 2020.[3] The RED has no binding sustainability requirements for solid biomass at the EU level, probably due to the challenges of establishing a harmonized scheme for a wide variety of biomass as well as the low sustainability risks relating to domestic biomass production.[2] However, the EC proposal issued in November 2016 on the promotion of energy from renewable sources reinforces the existing EU sustainability criteria for bioenergy by extending the scope to cover both biomass and biogas for heating, cooling, and electricity production.[4]

Regarding biomass sustainability, there are concerns expressed by some non-governmental organizations on the sustainability risks of production, and to a lesser extent, transport and use of solid biomass, which are not covered under the current RED sustainability criteria.[5,6] Possible risks include reduction in carbon stocks when removals exceed annual productions in forests; energy generated using biomass may not lead to substantial GHG savings compared to fossil fuels; competition between energy and material use (among pulp & paper, energy, and construction industries); and unsustainable forest management and negative impacts on biodiversity and quality of land. Other issues such as indirect land-use change (iLUC), impacts on water resources and the environment, land right conflicts, and non-compliance social regulations have also been identified.

In Europe, forest biomass for energy is largely a complementary co-product of wood material/ fiber products, and therefore it is unlikely that bioenergy demand is associated with direct deforestation on a large scale in Europe.[3] Non-governmental organizations (NGOs) have, however, claimed unsustainable sourcing practices of woody biomass for a number of specific cases in the EU.[6] Although the volumes of solid biomass used for energy production are relatively small compared to overall solid biomass use, the volume of solid biomass imported from outside the EU for energy use has been increasing in recent years[7] and the sustainability of this sourcing has been questioned, especially from the US South to the EU.[6]

The main importing countries for solid biomass in the EU are the UK, Belgium, the Netherlands, and Denmark; these countries are also the focus countries of this paper. There is increasing pressure from various stakeholders for the implementation of sustainability requirements covering sustainable production and use of solid biomass for large-scale heat and energy generation. In the absence of sustainability criteria for solid biomass being set at a European level, the EC has encouraged its member states to develop their own sustainability criteria for solid biomass based on EC recommendations on addressing land use, land-use change, and forestry as well as GHG emissions performance.[3] As a consequence, a number of industrial bioenergy users (e.g. RWE, Engie, Drax Power, Dong Energy) have voluntarily developed their own sustainability criteria for sourcing biomass. Also, a number of European countries have already implemented support and voluntary schemes to govern the sustainable production and use of solid biomass. Belgium has implemented three Green Certificate schemes (GCs) for solid biomass used for electricity generation that include sustainability principles since 2002. The system(s) are expected to be revised shortly and to become more comprehensive. The UK has implemented binding sustainability criteria for sustainable biomass used to produce heat and power since 2016. Denmark has also implemented a voluntary scheme to support the sustainable use of solid biomass for energy production in 2016. In the Netherlands, sustainability criteria have also been developed for solid biomass used for co-firing and large-scale heat production. Details are still being finalized, such as the means of verification and eligibility of existing sustainable forest management (SFM) systems.

The need for assessment of national sustainability requirements for solid biomass

Review of the national support and voluntary schemes showed that each of the focus countries has its own sustainability requirements. Differences between national sustainability requirements cause trade barriers for solid biomass, and represent an administrative cost in demonstrating compliance. Previous analyses on the development of sustainability criteria for solid biofuels recommended harmonization of certification systems for sustainable biofuels.[8,9] This paper emphasizes the importance of reviewing sustainability criteria in the focus countries to understand the requirements in demonstrating sustainability compliance of solid biomass used for bioenergy. The paper additionally aims to provide solutions which help facilitate sustainable biomass trade for suppliers and generators of solid biomass as well as recommendations for policymakers setting sustainability requirements.

In detail, this paper focuses on:

- Assessing and comparing the current proposed sustainability requirements in the focus countries.

*The most common applications of biomass for heat and power production reduce GHG emissions by 55–98% compared to the fossil fuel mix. 23

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- Identifying differences and evaluating the comprehensiveness of sustainability criteria and reporting requirements.
- Investigating differences between national criteria linked to sustainable forestry management with voluntary certification systems and verifying which systems are recognized in the national support schemes.
- Providing recommendations for improvement and the possible alignment of criteria towards a system of harmonized sustainability criteria and reporting requirements.

In this paper, the support schemes and their associated sustainability requirements in the focus countries are first introduced, and the methodology used to review these schemes is described. The process of consultation with stakeholders regarding policy development, scheme updates, and opinions regarding the level and inclusion of various sustainability requirements are presented. Results of the study are shown in the next part. Finally, conclusions are presented and recommendations are made for further improvements to national sustainability requirements.

Sustainability criteria and sustainability requirements

To clarify the study focus and also to align different sustainability issues identified in the national support and voluntary schemes, the terms sustainability requirement and criteria are defined. They will be used intertwined. More explanation is provided in Appendix 1 (Supporting Information).

Differences of voluntary certification systems and national schemes

Several voluntary certification schemes are recognized and used in the four investigated countries to demonstrate compliance with national sustainability requirements. Each voluntary certification scheme has a specific scope for what it certifies. For example, the scope of current certification schemes may cover the legal and sustainable sourcing of forest biomass but not GHG footprint calculations.

National support schemes for solid biomass used for bioenergy production

UK legislation on sustainability of solid biomass for bioenergy production

The UK aims to produce 15% of its energy from renewable sources in gross final consumption of energy by 2020 and biomass is expected to make a significant contribution to delivering the UK's renewable energy target. [10] The UK government has established sustainability requirements for biomass feedstocks in relation to the sustainable sourcing and production of biomass. The Department for Business, Energy and Industrial Strategy (BEIS) and the Department of Transport introduced four support mechanisms: the Renewables Obligation (RO),[†] the Renewable Heat Incentive (RHI),[‡] the Contracts for Difference (CfD),[§] and the Renewable Transport Fuel Obligation (RTFO).[**] Each of these includes sustainability requirements for solid biomass. Among these initiatives, the RO is the UK government's main support mechanism to incentivize deployment of large-scale renewable electricity generation.[10] The RO mechanism has been further investigated in this paper as it contains all the relevant sustainability requirements set out in UK legislation.

The aims of the sustainability requirements for solid biomass under the RO are to deliver real GHG savings whilst assuring that solid biomass is produced in a way that does not give rise to deforestation or degradation of habitats or loss of biodiversity. It also aims to guarantee that solid biomass is cost effective as well as its production and use does not give rise to unintended consequences.[10]

Belgian mechanisms to promote renewable bioenergy from solid biomass

Belgium sets a target to achieve 13% of renewable energy in the final energy consumption until 2020.[2] In 2002, the GC mechanisms to promote the usage of renewable sources for electricity production through a quota system based on obligations, tradable certificates, and minimum prices as well as the sustainable certification and subsidies for the investment and utilization of renewable electricity were introduced.[11] The trade of certificates is subject to federal legislation, while the quota obligations are defined in regional regulations. Electricity suppliers need to show evidence that they have supplied a certain quota of renewable energy determined by three regions Flanders, Wallonia, and Brussels-Capital (which have almost the

[†]RO is the main support mechanism for large-scale renewable electricity projects in the UK.

[‡]RHI includes Domestic RHI for homeowners, private landlords, social landlords and self-builders as well as Non-domestic RHI to provide payments to industry, businesses, and public-sector organizations.

[§]CfD is the long-term contracts to encourage investment in new, low-carbon generation.

[**]RTFO is the mechanism to support the UK government's policy on reducing GHG emissions from vehicles by encouraging the production of biofuels that do not damage the environment.

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same requirements so that they are integrated as one region for further investigation) to their final consumers.

The quota systems do not include sustainability requirements for various types of renewable energy but they require evidence of sustainable forest management for forest biomass including certified or at least evidence such as type of raw materials as well as energy and CO2 balance of the supply chain to an accredited inspection a proof of compliance with responsible management of the forests, controlled impact on environment and enforcement of legislation.[12] In Flanders, additional requirements relating to the cascading use of biomass have been established.

Danish Industry Agreement

Denmark has a relatively high share of renewable energy and aims to achieve 30% in gross final energy consumption in 2030.[13] Biomass currently presents the largest share of the total renewable energy supply, equaling 65%, including mostly wood, biodegradable waste, and straw.[14]

There are no mandatory sustainability requirements for solid biomass used in the Danish energy sector but a voluntary Industry Agreement[††] (IA) was established by the Danish District Heating Association and the Danish Energy Association in 2014. Stated in the agreement, the IA aims to support the use of solid biomass (chips and wood pellets) for energy production in Denmark. The IA attempts to comply with the Danish framework for sustainability in terms of the environment, health and safety and climate. The combined heat and power producers are themselves responsible, the producers document and satisfy requirements for sustainability through a third-party. The requirements for sustainable biomass were developed based on the most comprehensive biomass sustainability legislation that existed at the time, namely the UK Sustainability Criteria For Solid Biomass.[15]

Dutch Agreement on Energy for Sustainable Growth

Jointly with Belgium, the Netherlands was one of the first countries in the EU that called for sustainability requirements for solid biomass at national level. The Cramer Commission specified comprehensive sustainability categories defined in a governmental project for sustainable production of biomass, including criteria for GHG emissions and carbon stocks, competition for food production and local applications of biomass, biodiversity, environmental impacts on water, air and soil as well as social wellbeing. Since then more voluntary certification schemes had been developed such as the Better Biomass, which are based on Cramer criteria.[16]

In 2009, the Commission for Biomass Sustainability was established with the aim of advising the Dutch government on several issues related to biomass sustainability including sustainability requirements for solid biomass. In 2013, the Netherlands Enterprise Agency (RVO) published the 'Energy Accord for Sustainable Growth' stating that biomass used for co-firing and heat production must meet several sustainability criteria. As part of the Dutch 2013 Energy Accord, the Sustainable Energy Production Incentive Scheme (SDE+) has been introduced including sustainability criteria set in legislation based on Better Biomass requirements, and additionally covering carbon debt, iLUC, and SFM requirements.

Methodology to compare sustainability requirements and evaluate the comprehensiveness of national support schemes

A four-step methodology was established to compare the sustainability requirements and evaluate the comprehensiveness of the national support schemes (see Figure 1).

The first step was analysis of the sustainability approaches that have been developed and applied as well as of the requirements for operators to demonstrate sustainability compliance to authorities. An initial review found that the UK has developed comprehensive criteria and these criteria were adopted as the baseline for the comparison of the national sustainability requirements. Although the evaluation was based on the UK requirements, it was also expanded to include additional requirements and criteria that are not included in the UK system such as cascading and carbon debt criteria. Primary data on the sustainability requirements and criteria in each country were obtained from official national documentation.

The sustainability requirements investigated were GHG emissions reduction, land-use criteria, carbon debt, iLUC, cascading use of biomass, local land right, chain of custody, and mass balance systems (clarification of these criteria is provided in Appendix 2, Supporting Information). For each requirement, the current level of compatibility was assessed and the possibilities for further harmonization are briefly discussed.

The second step was to study several voluntary SFM certification systems. National schemes also recognize a

[††]The agreement is binding for industry to demonstrate sustainability compliance of biomass use for bioenergy

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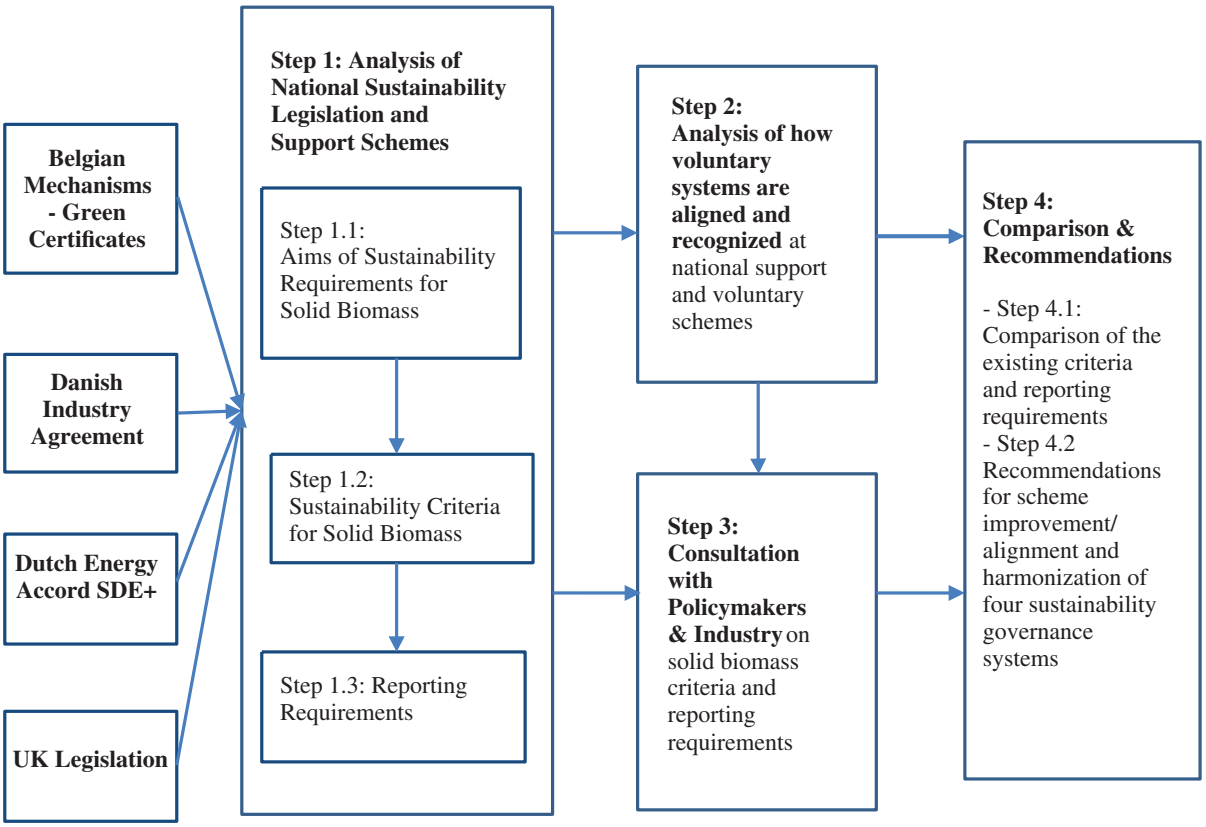

Figure 1. Step-wise for comparison and possible harmonization of national sustainability support and voluntary schemes.

number of SFM certification systems as a way of assuring that biomass meets part or all of the national sustainability criteria and requirements. This study therefore reviews relevant SFM schemes to determine how they meet national sustainability requirements and how they might potentially be recognized in the national schemes.

The third step consisted of the consultation and discussion with various stakeholders about the comprehensiveness of sustainability criteria, verification, and certification processes of sustainable solid biomass, as well as the implementation timeline of the support schemes in the focus countries. Consultation also helped inform understanding of stakeholders' opinions on how national support and voluntary schemes are established. Questionnaires were sent to several relevant stakeholders and additional information was obtained by two international workshops in which primary policymakers and industry representatives from each of the focus countries participated.

The final step was to review the outputs of the previous steps and compare the sustainability criteria and reporting requirements of these schemes. Recommendations for possible improvement and the harmonization of sustainability certification systems, also based on the stakeholder consultations, in the four countries were formulated.

Results and discussion

Consultation with stakeholders on national schemes and the sustainability requirements

The stakeholders presented at the two workshops (in 2014 and 2015) and individual interviewees provided valuable input and feedback on the conclusions and recommendations of this paper. In this section, first the main findings and conclusions from the workshops are summarized (a longer version is included in Appendix 3, Supporting Information) before own conclusions and recommendations are presented.

In general, the consulted stakeholders recognized the importance of establishment and implementation of sustainability requirements on the short term at a national level. Utilities and consultants from both the EU and exporting countries also indicated that significant time

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and resources are needed to demonstrate both different calculations methods for GHG emissions as well as compliance with other sustainability requirements. Industry representatives also indicated that data collection and sustainability demonstration at the forest unit level is also complicated and challenging to carry out. Therefore, sustainability requirements in various schemes that are interchangeable/mutually recognized/harmonized should be considered.

Consulted stakeholders, in particular policymakers, agreed that sound scientific methods to determine carbon debt and carbon stocks (including definition, measurement, and management) should be further developed. Representatives from the exporting countries stated that EU policy may have influence on the sustainability certification and biomass market in the sourcing regions. Most of the stakeholders suggested benchmarking sustainability criteria in diverse voluntary certification systems used by biomass suppliers and generators could help them easily demonstrate sustainability compliance to national sustainability requirements. All stakeholders agreed that sustainability criteria set at EU level should be considered to be implemented in the near future.

Comparison of national approach and sustainability requirements

Aims of national legislation, and support and voluntary schemes for sustainable biomass

The overarching aims of the national support and voluntary schemes in the four countries have both similarities but also significant differences. The Belgian mechanisms mainly seek to optimize the GHG emission reduction, while the UK mechanisms address a wider range of sustainability requirements as well as cost-effectiveness of bioenergy. Although the Danish IA and the Dutch Energy Accord have not stated specific aims, their ambitions toward sustainable biomass use are also defined indirectly through the establishment of a comprehensive set of sustainability requirements.

Scope of biomass feedstocks and bioenergy application

The scope and comprehensiveness of sustainability requirements in the four countries are relatively different. Regarding the scope of feedstock use, forest biomass feedstocks are included in all national schemes, and in Denmark agricultural feedstocks are not included. Regarding the bioenergy application scope, three countries use solid biomass for electricity and heat production, namely Denmark (combined heat and power), the Netherlands (co-firing in existing coal power plants and large-scale heat producers) and the UK (heat, power plants, and co-firing in existing coal power plants) whilst in Belgium the scope is only for electricity production. A summary of feedstock inclusion and bioenergy application scope in national schemes is shown on Table 1.

Belgium, the Netherlands, and the UK apply legally binding sustainability requirements for solid biomass linked to the national support schemes, for example biomass that does not meet the sustainability criteria could in theory still be used, but would not be eligible for financial support or meet the national targets and thus in reality would be very unlikely to occur. Solid biomass used in the focus countries needs also to be legal under the European Timber Regulation.

In Denmark, compliance with sustainability requirements is regulated through a voluntary industry agreement (sustainability criteria in IA are semi-bindings), for example not directly linked to the support scheme(s) of sustainable biomass use. However, there are indirect subsidies for biomass energy in the form of (heavy) taxation of fossil fuels, that competes with tax-free biomass for heat production as well as direct renewable energy subsidy for electricity produced on biomass. These subsidies require that the biomass is uncontaminated (e.g. no waste or waste wood from processing).

Table 1. Overview of the feedstocks and bioenergy application scopes.

Country	Scope of feedstocks			Scope of bioenergy application	
	Agricultural	Energy crop	Forestry	Heat	Power
Belgium – Wallonia & Brussels Capital	√	√	√		√
Belgium - Flanders	√	√	√		√
Denmark			√	√	√
Netherlands	√	√	√	√	√
UK	√	√	√	√	√

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Table 2. Overview of methodologies to calculate GHG emissions in the four countries.

	RO, RHI, CfDs - UK	GCs - BE		IA - DK	SDE+ - NL
		Wallonia & Brussels Capital	Flanders		
5.2.1.1 Calculation method	Own tool but based on BioGrace II & RED tools	Own method based on emission reduction, following RED-methodology	Own method based on fossil fuel use along supply chains	Verified calculation tool BioGrace II	Verified calculation tool BioGrace II
5.2.1.2 Limit (compared with 1990 baseline level)	60% (2016) 70% (2025)	No limit, but growing obligatory quota	No limit, but growing obligatory quota	70 % (2016) 75 % (2025)	70% (2016)
5.2.1.3 Timeline of implementation	Already implemented (March 2016)	Already Implemented since 2002	Already Implemented since 2002	Already implemented (January 2016)	Already implemented (2016)

The coverage of sustainability requirements including GHG, land-use criteria and other sustainability requirements is most comprehensive in the UK, the Netherlands, and Denmark while it is currently rather limited in Belgium (Belgian regulation is expected to be changed in 2017). This will be described in more detail in the following sections. Regarding the recognition of voluntary schemes, several voluntary certification schemes are already recognized in the UK, Belgium, and Denmark. The Netherlands is still in the early stages of benchmarking certification schemes. An overview of national sustainability requirements and possibilities for harmonization are summarized in Table 3.

Evaluation of sustainability requirement comprehensiveness, assessment of scheme harmonization, and alignment

Greenhouse gas emissions criteria

These cover GHG emissions in the supply chain with limited inclusion of carbon storage and land use change emissions (except for agricultural and waste residues).

- **Calculation tool:** BioGrace-II[17] is used in Denmark and the Netherlands to calculate GHG emissions in which information in various steps of the supply chain including cultivation, handling and storage of solid biomass, processing plant, and inland and intercontinental transport is used. One example is the cultivation stage of energy crop where data of crop yield, moisture content, co-product, energy consumption and agrochemical are collected to estimate the emissions of CO2, CH4, N2O which will be ultimately converted to CO2 emission equivalent.
  The UK has developed its own GHG emission calculator – the Biomass & Biogas Carbon Calculator – which incorporates both the RED approach and the BioGrace-II GHG calculation tools.[3] The operator must enter the GHG emission figure with options for known, exempted, and unknown biomass. Where a GHG emission figure is entered, the system determines if the GHG criteria are met by reviewing the calculated figure against the relevant GHG threshold.
  In Wallonia and Brussels-capital region, the GHG accounting is based on the RED-methodology and additionally includes emissions from the disposal of waste. In Flanders, GHG emissions are calculated considering the total amount of fossil energy spent in the supply chain.[12]
- **GHG emissions limits**: Compared to the 1990 baseline level, the Dutch and Danish requirements are the most ambitious requiring a 70% emission reduction as of 2016 to 75% in 2025. The UK requires a GHG emissions reduction of 60% from 2016 rising to 70% as of 2025 (the limit increase is not necessarily constant over time in these three countries). In the Walloon and Brussels-Capital regions the number of GCs issued depends on the emission reduction (the more reduction, the more GCs are issued) whilst in Flanders the number of GCs issued is based on fossil energy use along the supply chains.

Table 2 presents the GHG calculation methods, emissions limits (over time) and timeline of implementation. These requirements are not closely aligned and the requirements for data collection and transfer along the supply chain are not similar (e.g. the number of data required by Belgium is very large but very small for UK). If requirements were agreed, harmonization of the GHG emission calculation methodologies might be possible.

Table 3 summarizes harmonization possibilities of and harmonization level of various sustainability criteria and

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Table 3. Summary of sustainability requirements and possibilities for harmonization.

	RO, RHI, CfDs RTFO - UK	GCs Wallonia–BE	GCs Flanders – BE	IA - DK	SDE+ - NL	Current Harmonization Level	Harmonization Possibilities	Note
I. Level of requirements	Legally binding to receive support	Legally binding to receive support	Legally binding to receive support	Voluntary	Legally binding to receive support	*Low*	±	Harmonization possible between the Netherlands and the UK
II. Timeline of implementation	March 2016	Already implemented	Already implemented	January 2016	To be determined	*Medium*	±	Harmonization possible between four countries
III. Sustainability Requirements Coverage								
Greenhouse Gas Emission:								
- Calculation method	✓	✓	✓	✓	✓	*Medium*	±	Harmonization possible between four countries
- Limit compared with 1990 level	✓	✓	✓	✓	✓	*Medium*	→	Harmonization possible between four countries
- Time of implementation	✓	✓	✓	✓	✓	*High*	→	Harmonization possible between four countries
Land Use:								
Sustainable forest management:								
Legal, sustainable sourcing & certification	✓	±	±	✓	✓	*Low*	→	Harmonization possible between the four countries
Forest productivity and well-functioning	✓	±	±	✓	✓	*High*	✓	Harmonization possible between four countries
Biodiversity protection	✓	±	±	✓	✓	*Medium*	✓	Harmonization possible between four countries
Ecosystems conservation	✓	±	±	✓	✓	*High*	✓	Harmonization possible between four countries
Feedstock categories	✓	±	±	✓	×	*Low*	→	Harmonization rarely possible between four countries
iLUC	×	×	×	×	✓		×	

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Table 3. Continued.

Other sustainability requirements								
Carbon debt	×	×	→	×	✓		×	
Compliance with laws & local rights[‡‡]	✓	±	±	✓	✓	*High*	±	
Chain of Custody	✓	±	±	✓	✓	*High*	±	Harmonization likely possible between Belgium, the Netherlands and the UK
Mass balance	✓	✓	✓	✓	✓	*Medium*	±	Harmonization possible between four countries
Cascading use of biomass	×	×	→	×	→	*Low*	±	Harmonization unlikely possible although possibly included in Flanders, Belgium, Denmark and the Netherlands
IV. Recognition of international voluntary certification schemes	✓	±	±	✓	→	*Medium*	±	Harmonization possible between the four countries
V. Sustainability reporting requirements								
Station capacity	✓	✓	✓	✓	✓		×	
Reporting procedure	✓	✓	✓	±	✓	*Medium*	→	Harmonization possible between the four countries
Legend		✓ Included in national schemes				✓ Harmonization is possible		
		± Partly Included in the national scheme				→ Possible harmonization in the future		
		→ Plans to be included in the national scheme				± Harmonization might be reached		
		× Not included in the national scheme				× Harmonization not possible		

[‡‡]It is required in the EU that every company must comply with national law (and local law) through EUTR. However, companies are not required to comply with other international conventions.

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requirements. Regarding the reporting requirements, they are not the main focus of the paper; therefore, more details are provided in Appendix 4 (Supporting Information).

Land use

Land-use-related criteria are considered based on the UK approach [10] covering sustainable forest management used for woody biomass; feedstock categories used for biomass that is neither wood nor derived from wood; and iLUC for all biomass types.

- **Sustainable forest management**: The main issues related to sustainable forest management requirements were investigated including legal, sustainable sourcing and certification; forest productivity and well-functioning; biodiversity protection and ecosystems conservation as the three main sub-criteria of sustainable forest management requirements which are defined in the national and voluntary schemes.

In general, Denmark and the UK require that forest residues from nature and landscape management (with no difference in requirements for round wood, forest residues or secondary feedstocks) only need to comply partly with sustainable management requirement to ensure soil quality to be maintained and where possible improved. Belgium (both Wallonia and Flanders) and the Netherlands have clear definitions of various residues (primary, secondary, and tertiary; Appendix 2, Supporting Information) and in general, they do not need to comply with requirements of carbon and land use changes. However, residues from nature and landscape management as well as from agriculture need to comply with sustainable management criteria.

For wood or derived from wood (other than an energy crop), the requirements below need to be taken into consideration.

+ *Legal, sustainable sourcing and certification*: The UK RO mechanism states that independent certification of the wood by any of the forest certification schemes that cover the RO sustainable forest requirements or evidence of legality as required by EU Timber Regulation (EUTR) can be used (Category A; Appendix 2, Supporting Information). Evidence that the wood fuel originates from a legal and sustainable source can also be provided in the form of alternative/bespoke documentary evidence that provides sufficient assurance that the source of the wood is legal and sustainable (Category B; Appendix 2, Supporting Information). The Danish requirements for sustainable biomass follow the UK Timber Standard as clarified in its Industry Agreement. In Wallonia and Brussels-Capital, several requirements for sustainable wood are currently being discussed, but it is uncertain what requirements will be included. In the Dutch SDE+ scheme, large forest management units (≥ 500ha) need to demonstrate compliance with SFM criteria at the forest level as of 2016. For biomass from small forest management units (<500 ha), certification is currently accepted at the regional pellet mill level. In Belgium, proof of legal and sustainable sourcing and production of biomass is also required to 90% of the total biomass used.
  Communication with Danish policymakers indicated that the Danish IA would be further developed but it is not clear to what extent of comprehensiveness. Harmonization seems only possible to a very limited extent, as the Dutch rules go into far more details than the UK and Danish requirements.
+ *Forest productivity and well-functioning*: the UK RO requires that productivity of the forest, ecosystem health and vitality are maintained. Similarly, the Danish IA states that the forests must be healthy and well-functioning, its productivity and ability to contribute to the global carbon cycle must be maintained. The Dutch SDE+ requires, health and vitality of the forest must be maintained and where possible enhanced. In principle, these requirements are closely aligned, however wording and statements need to be discussed and agreed by national policymakers and relevant stakeholders. No requirement is included in the Belgian mechanisms.
  SFM systems such as FSC (*Forest Stewardship Council),* PEFC (Programme for Endorsement of Forest Certification), SBP (Sustainable Biomass Partnership), and SFI (Sustainable Forestry Initiative) could be used to prove the compliance with these requirements in the UK and Denmark. The SFM schemes, which are already recognized in other countries, might also be accepted in the Netherlands as stated in the draft verification protocol; therefore, harmonization might be possible among all four countries.
+ *Biodiversity protection and ecosystems conservation*: These requirements are part of the timber standard and feedstock categories included in Denmark, the UK, and the Netherlands. UK legislation requires that harm to ecosystems is minimized and biodiversity needs to be maintained; and the Danish IA states that fundamental conditions of the ecosystem must be preserved. The Dutch SDE+ requires that biodiversity, high conservation value areas, the regulating effect and the quality of the forest must be maintained and where possible enhanced. The Belgian mechanisms do not require suppliers and generators to provide proof of sustain-

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ability but they encourage solid biomass suppliers and bioenergy generators to include these requirements in their reporting.[18,19]

In summary, the requirements regarding biodiversity protection and ecosystems conservations in the four countries are not the same. Alignment of these requirements would be possible among the four countries if policymakers agree on the terminology and level of details regarding biodiversity protection and conservation.

- **Feedstock categories** (all for types of biomass)

+ *Definition of feedstock categories:* The UK RO states that biomass cannot be obtained from land that at any time during or after January 2008 was land designated for protecting nature; a highly biodiverse grassland; peatland and a continuously or lightly forested area. Similarly, the Dutch legislation requires biomass not to be sourced from permanently drained land that was classified as peatland on January 1, 2008, from land that was converted from a wetland to an alternative. The Dutch legislation additionally requires that biomass is not sourced from production forests converted from natural forest after December 31, 1997.
  Wallonia and Flanders have a similar definition of biomass feedstock categories including waste, residues, products, and co-products but there are no further details. Information in the UK and the Netherlands are much more comprehensive. The Danish IA does not have requirements for biomass originating from agriculture and bioenergy crops.
+ *Reporting requirements linked with feedstock categories and sustainability criteria*: Reporting requirements as a proof of sustainability compliance with national schemes are clarified in the four countries. Depending on different feedstock categories, the degree of reporting requirements differs significantly across countries. In the UK, waste and biomass wholly derived from waste are exempted from land-use change and GHG emission criteria, whilst residues from agriculture and forestry are required to be included in annual reporting for land use change and partly for GHG emissions criteria (only emissions during and from collection and processing need to be reported). Biomass products and co-products[§§] are required to comply with land use and full life-cycle emissions criteria.
  In the Netherlands, reporting requirements are specified for various biomass feedstocks. All woody biomass need to comply with requirements of sustainable management, carbon, and land-use change.*** Residues from agriculture, nature and wastes only need to comply with GHG balance and chain of custody criteria.

There are various classifications of biomass feedstocks and accompany reporting requirements are not equivalent in the Netherlands and the UK. One example is that the Dutch SDE+ requires carbon debt and iLUC to be applied for woody biomass which is only from large forest units. Another example is that the UK RO has developed feedstock categories for various biomass sources whilst the Danish IA only focuses on forest biomass. Dutch SDE+ includes land sustainability requirements also for solid biomass originating from agricultural waste and residues. Full harmonization of these criteria is not yet possible and can only be achieved if policymakers have a clear definition of land categories and agreement of what biomass sources need to demonstrate sustainability compliance.

Other sustainability requirements (for woody and agricultural biomass which are not residues)

- **Indirect land-use change**: The Dutch SDE+ requires that biomass sourced from new bioenergy plantation systems that were planted after January 1, 2008 must have a demonstrably low iLUC risk in which risk can be calculated following the Low Indirect Impact Biofuels methodology. [20] The UK legislation does not include iLUC criteria and it is briefly mentioned in the Danish IA that there are currently no agreed methods for calculating compliance with the requirements relating to carbon cycle, maintenance of forest carbon stock, iLUC, and indirect wood-use change (iWUC). The Danish industry aims to develop methods to document and formulate more detailed criteria.[15]
  Harmonization of iLUC criteria is unlikely possible in the future as agreement on iLUC definition and risk assessment are still being debated in the focus countries.
- **Carbon debt:** The Dutch SDE+ indicates that the forest management units where the all type of wood is sourced must be managed with the aim of retaining or increasing carbon stocks in the medium or long term.[20] The Dutch carbon debt criterion focuses mainly on

[§§]Biomass from co-products (e.g. sawdust) must meet the sustainability requirements of round logs in both the UK and DK as it is easier to demonstrate compliance for round logs than sawdust.

***Woody biomass from small forest management units of less than 500 ha do not need to compliance with indirect land use change requirement

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forest stumps (biomass is not sourced from stumps unless these stumps had to be removed from the site for reasons other than wood or biomass production) and harvested forest (in which less than half the volume of the annual roundwood harvest is processed as biomass for energy generation).

The carbon debt criterion is briefly mentioned in the Danish IA[15] but is not yet defined in the UK, Belgium nor on international level. The level of compatibility between the four countries is currently very low and harmonization of criteria covering carbon debt is unlikely in the near future.

- **Compliance with related laws and local rights:** The Danish IA requires compliance with local laws regarding social, work rights: child labor, and discrimination are not permitted. The Dutch SDE+ has defined a compliance requirement with not only local but also international laws and regulations that might be more complex to comply with, whilst the UK has requirements of labor, welfare, and health and safety at only local and national level. This criterion is not clearly defined in Belgium but cross-compliance with related legislation is encouraged.[18] However, each country requires compliance with the EUTR and therefore this should confer a high level of harmonization in terms of compliance with related laws and local rights.

- **Chain of Custody (CoC):** The Dutch SDE+ defines that a chain of custody must be in place that covers the entire chain from the first link to the bioenergy producer and that the CoC also quantifies the greenhouse gas emissions of each individual link in the supply chain [20] (Appendix 2, Supporting Information). The GCs in Flanders and Wallonia/ Brussels-Capital define that CoC is the traceability system for tracking biomass inputs from their production to the inputs at the power generation site and that via the traceability system, it is possible to know each step of the chain. UK legislation defines CoC for both agricultural and forest products as the traceability in the supply chain from raw material to end products.[10] The CoC requirements are not yet defined in the Danish IA but it will likely adopt those of the UK.

Definition and requirements of CoC are rather similar in Belgium, the Netherlands, and the UK and if policymakers would agree with the CoC definition, harmonization might be possible between the three countries.

- **Mass balance**: UK legislation permits the mass balance method to be used where different consignments of biomass are mixed at the generating station or at any point in the supply chain. A minimum of 70% of the mixed biomass needs to meet all sustainability requirements and the remaining 30% meet the legality requirements. The Danish IA follows the UK approach. The Dutch SDE+ scheme has similar requirements that the mass balance requirements may apply to the mixing of biomass, and hence a single physical delivery could also include biomass with different properties. Also in Belgium, mass balance is used in order to ensure that green energy produced from solid biomass is achieved. A harmonization therefore may be possible among the focus countries if policymakers could agree on the mass balance approach.

- **Cascading use of biomass**: There is no consideration of biomass cascading use in the UK whilst it will likely to be required in Flanders but there is not yet a consensus on the definition of cascading.[21] Consultation with policymakers from Wallonia and Denmark has revealed that this criterion may be included in their national schemes in the future but it is not yet clear to how and what extent.

Harmonization of cascading requirements is not yet possible and it is still difficult to predict how cascading use of biomass will be defined in different countries as well as how the level of sustainability requirement is agreed.

Recognition of voluntary SFM schemes

Biomass suppliers and generators may use more than one voluntary scheme or a combination of voluntary schemes and collect other information (some examples are shown on Table 4).[10] The suppliers and generators can also use voluntary schemes approved by the EC to demonstrate compliance with the national sustainability criteria and requirements.[15,18,19,22] Use of these schemes as such may help to reduce cost burden and complexity in providing evidence of sustainability compliance of solid biomass where sustainability criteria are required and may therefore facilitate biomass trade from various sourcing regions.

The SFM systems such as FSC Controlled Wood (Company), FSC Controlled Wood (Forest Management Enterprise), PEFC Controlled Sources, SFI Fiber Sourcing and SBP (which also uses FSC/ PEFC/ SFI standards) are recognized in the UK for many of land-related criteria and SFM requirements. Belgium and Denmark have also indicated their acceptance of FSC, PEFC forest certification, and SBP certification as well as verification from an organization that is EU-approved [23] but it is not clear regarding the levels of sustainability criteria inclusion and comprehensiveness that meet national requirements.

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Table 4. Summary of proof of compliance of SFM certificates in the UK (adapted from the UK 2015 benchmarking exercise against the feedstock categories for woody biomass).

Name	FSC Controlled Wood (Company)	FSC Controlled Wood (Forest Management Enterprise)	PEFC Controlled Sources	SBP	SFI Fiber Sourcing
(Benchmarked version)	FSC-STD-40-005 (Version 1-0)	FSC-STD-30-010 (Version 2-0)	PEFC ST 2002:2013 (Controversial sources)	SBP March 2015	SFI Fiber Sourcing 2015-2019
Wood fuel criteria					
Consistency with the Forest Europe SFM Criteria	Not assessed as criteria 1.2 and 1.3 are compliant			Yes	Yes
Standard setting process	Yes	Yes	Yes	Not accessed as criteria 1.1 is compliant	
Standard change process	Yes	Yes	Yes		
Harm to ecosystems is minimized	Not covered: except for the protection of biodiversity.			Yes	Partial
Productivity is maintained	Not covered	Not covered	Not covered	Yes	Yes
Health and vitality of ecosystems is maintained	Partial	Partial	Partial	Yes	Partial
Biodiversity is maintained	Partial	Partial	Partial	Yes	Partial
Compliance with laws relating to labor, health and safety, welfare of workers	Partial	Partial	Partial	Yes	Partial
Land-use rights, grievances and disputes, health and safety and workers' rights	Partial	Partial	Partial	Yes	Not covered
Regular assessment	Yes	Yes	Yes	Yes	Yes
Regional risk based approach					
Definition of a region	Yes	The assessment of a regional risk-based approach is not applicable	Yes	Yes	Yes
Woodfuel must be traceable back to a supply base within the region	Yes		Yes	Yes	Yes
Evidence must demonstrate a low risk of non-compliance	Yes		Yes	Yes	Yes
Audit and certification	Yes	Partial	Yes	Yes	Yes
Accreditation	Yes	Yes	Yes	Yes	Yes
GHG emissions requirements					
Calculation method	Draft available but not yet recognized	Draft available but not yet recognized	Draft available but not yet recognized	Available but not yet recognized	No

In the Netherlands, FSC 100% compliant, PEFC 100% compliant can be used to demonstrate compliance with the sustainability requirements regarding soil quality, carbon, and sustainable forest management as well as supply chain management. In addition, the Dutch SDE+ scheme only recognizes FSC Controlled Wood and PEFC Controlled Sources for the controlled biomass compliance and SBP for supply chain management. And none of the SFM reviewed schemes covers residual flows from nature and landscape management (biomass animal and arable products), biogenic waste and residual products as set in Dutch sustainability requirements or residues from agriculture; aquaculture and fisheries as set in the UK legislation. In principle, comprehensiveness and coverage of sustainability criteria in SFM schemes will decide the level of recognition in national sustainability support systems.

SBP Standard 5 defines the methodology for collection and communication of GHG data along the supply chain enabling generators to demonstrate compliance to their regulators. SBP Standard 6 provides a mechanism for the certification of the GHG calculation of the generator. PEFC has published a draft mechanism for the transfer

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of GHG emission data along the supply chain of solid biomass. The FSC Carbon Footprint Procedure aims to provide a method to calculate carbon footprint and therefore indicate possibilities to be acknowledged as the GHG criteria compliance in those countries but the procedure is not yet implemented.

In conclusion, voluntary certification systems are partly recognized in the national schemes (these systems do not meet requirements such as iLUC and carbon accounting). However the SBP is aligned with most of the UK sustainability criteria, also FSC 100% compliant and PEFC 100% compliant are fully recognized in the Netherlands (but some individual PEFC national standards will be benchmarked and might not be accepted). [24] In order to be recognized on various national legislations, voluntary certification schemes for sustainable solid biomass need to include additional sustainability requirements which are not easily achieved due to different focus and specific requirements of various national schemes.

Conclusions and recommendations

Conclusions

This paper has shown a similarity of sustainability criteria that are covered in the national support schemes, but that the definitions and level of ambition differ. There are only a limited number of sustainability requirements that are compatible and/or could be fully harmonized. These focus on woody biomass including biodiversity protection, ecosystems conservation, forest productivity and well-functioning forests. This paper also found that the Dutch SDE+ scheme has several sustainability requirements that are not included in the other countries, and it is therefore likely to hinder Dutch generators importing biomass.

Chain of custody

The Dutch requirements are more detailed and extensive than for other countries and this creates challenges in demonstrating compliance and will limit the trade between different markets. Those requirements will also lead to difficulties in aligning the Dutch SDE+ with other national schemes.

GHG thresholds and saving approaches

In the four countries GHG emissions thresholds and saving approaches that are not aligned. Varying threshold levels are not necessarily a barrier to trade, but they could lead to leakage, for example all biomass that meets the high threshold level of GHG emission savings will be imported by country A, while country B with a lower threshold will import biomass with lower GHG savings. If solid biomass leakage occurs, it limits the effectiveness of national support schemes dedicated to biomass sustainability in the country with stricter sustainability requirements.

The exact requirements for data collection of GHG emissions and other sustainability issues are only complete in the UK and the Netherlands, whilst information is not fully comprehensive in Belgium and Denmark. However, there is a possibility that the GHG calculation methods and thresholds could be aligned as the national schemes all base their GHG calculator on the RED calculation method. The distinction between different biomass feedstocks is decisive in determining whether certain types of biomass meet the GHG emission reduction requirements in each country.

Carbon debt and iLUC

Besides requirements for GHG emissions, criteria to limit the risk of decreasing carbon stocks in the medium or long term as well as leading to indirect land use change are currently being introduced and tested in the Netherlands, and Denmark is considering introducing these criteria in the future.[15] It remains to be seen whether the four countries will choose similar approaches, and whether these can then be harmonized.

It is noted that in all four countries, sustainability criteria and requirements apply only to large-scale industrial use whilst use of wood pellets for heating in households (a substantial share of the total wood pellet demand in Europe) are not in place due to the difficulty in monitoring small-scale users.[2] Similarly, there is a lack of comprehensive sustainability criteria for solid biomass used in other sectors (both traditional such as paper and construction, and new such as bioplastics and biochemical),[3] although legality of wood based products in the EUTR and sustainability are included in some cases (e.g. Timber Procurement Policy in the UK or Sustainable Timber Procurement in the Netherlands). If sustainability requirements are only mandatory for (a limited number of) bioenergy applications, but not for others material purposes, this may lead to leakage, for example the use of unsustainably produced feedstocks for residential heating or biochemical production. At the same time, inclusion of criteria for GHG emission reduction, iLUC, carbon debt, etc., for other end uses would further complicate matters and further reduce the chances to align and harmonize the national requirements.

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Finally, while the data and information supporting this study were collected with great care and verified with interviews with experts, the accuracy of all data presented in this report cannot be fully guaranteed. Also, over the course of the study (January 2014–December 2016) policies have changed, and are likely to continue to do so in the future. Therefore, the results and implications of this study may change even in the short term.

Recommendations

In the short term and outlook, opportunities for harmonization will depend on policymakers and other stakeholders' willingness to change existing legislation and support schemes to allow for more harmonization. At the same time, different stakeholders pursue different interests in the focus countries, leading to different outcomes (as illustrated in particular by the Dutch case), thus limiting the opportunities for harmonization further. Ultimately, a decision at EU level regarding the use of GHG emission calculation tools, data collection and default values for biomass types would be best for biomass suppliers and producers, as it would likely bring greater consistency. Ideally, a single authority such as the EC Joint Research Centre could provide information related to GHG emissions. This would already lead to a basic level of harmonization.

In 2015, the EC issued the Energy Union Strategy and announced that it would only come forward with an updated bioenergy sustainability policy as part of a renewable energy package for the period after 2020. In late 2016, in its proposal for the new directive on renewable energy, the EC indicated that existing various national support schemes have led to a sub-optimal situation and this has in turn negatively impacted investor confidence.[4] The proposal includes some principles for support schemes that member states can adopt for the protection of investors against retroactive changes and also proposed sustainability criteria (developed for forest biomass alongside a requirement to include emissions of land us, land use change and forestry in national commitments under the Paris agreement) that should be considered and included as necessary at the EC level. The proposal will be debated in the European Parliament and Council in 2017, and it is still unclear when a final agreement on such general sustainability criteria can be achieved.

Furthermore, regular structured information exchange and discussion among policymakers and industry on ongoing legislative developments in all countries implementing national requirements is recommended as this may aid future harmonization or at least avoiding more divergence. As legislation for solid biomass sustainability is being drafted and updated, dialogue between those stakeholders (policymakers, industry, academics, NGOs, and others) should be organized on a regular basis and at an international level to achieve common understanding on sustainability requirements for solid biomass as well as to increase the possibilities of harmonization. More discussion on several issues such as carbon debt, iLUC, and biomass cascading could also be useful to formulate practical yet comprehensive sustainability criteria.

Regarding cascading use, solid biomass used for heat and power generation is generally low value and a large proportion of woody pellets are imported, particularly from North America.[25] It is difficult for US suppliers to comply with the cascading requirements as it is still unclear what criteria are used to measure and how cascading will be implemented. A clear definition for cascading is therefore recommended. In general, agreement on common criteria definition, the level of sustainability requirement should be achieved first among various countries before specific legislation could be designed and applied for in a particular country. Awareness of requirements and guidance for biomass suppliers and generators is also important to enable them to demonstrate compliance.

In addition, the development of a harmonized certification scheme that could be used to meet criteria in all countries is recommended. The SBP is currently the only certification scheme that was developed to meet this goal, and is recognized in the UK and Denmark and is being used to demonstrate compliance in Belgium. Given the anticipated changes in the four countries, its standards will likely have to be adapted and extended. Much effort is required including consultation and discussions with national policymakers and related stakeholders to structure such a comprehensive certification system.

One particular issue is the amount of woody biomass that may be sourced from SFM-certified forests at acceptable costs – which is probably limited. The UK risk-based approach seems to be working as a (at least temporary) solution to demonstrate sustainable biomass production for export to the European Union. Also, the Dutch system allows for such a risk-based assessment, but has already put a sharp timeline that will only be possible for small forest owners and only until 2020. Given the limited amount of certified biomass currently available in many sourcing regions, and the fact that this is not likely going to change rapidly in the short term, it is recommended that national policymakers develop policies that will incentivize the uptake of SFM certification in the sourcing regions in the

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short-to-medium term, in particular to collaborate with forest owner for solid biomass certification in the South-East USA. Solutions such as group certification for small-holders or provision of an economic incentive (which may somehow distort market prices) could be ways to increase the uptake of SFM certification and at the same time also to discuss and determine which risk levels are acceptable on the short and medium term. Risk-based approaches to demonstrate compliance with, for example, SFM and legal requirements also carry challenges. Having agreement between countries as to what risk levels (and thus ultimately which sourcing regions) are acceptable would also reduce trade barriers and prevent leakage effects.

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