Approaches to creating trust in sustainability of bioenergy through effective governance

Summary of findings under Objective 2 of the IEA Bioenergy inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains"

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Authors

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Preface

The sustainability of the production and use of liquid and solid biofuels is under continued scrutiny. While this subject is one of great complexity, it is nevertheless one that must be addressed if we should realize the potentials of bioenergy to contribute to a more sustainable future. The IEA Bioenergy inter-Task project 'Measuring, governing and gaining support for sustainable bioenergy supply chains' was launched to address this challenge from three points of view, thus aiming at answering the questions:

1. How to measure and quantify progress towards more sustainable practices?
2. How to improve the input and output legitimacy of existing and proposed governance systems, with input legitimacy relating to the quality of stakeholder involvement, and the output legitimacy relating to the effectiveness with which a system achieves sustainability goals?
3. How to engage more successfully with the broad range of stakeholders so that policies and sustainability governance are perceived as legitimate and help build up social capital, trust and support among all stakeholders?

This report seeks to answer the second of these questions, based on a number of case studies conducted under the inter-Task project. Twelve of the case studies were made possible through the IEA Bioenergy funding (see Annex I).

In order to engage with other colleagues working on the same topic, an open conference - "Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes", 17-19 April 2018, University of Copenhagen, Denmark - was co-organised by IEA Bioenergy Task 43 and networks under the Nordic Council of Ministers, including the SNS-NKJ network activity "Effect of bioenergy production from forests and agriculture on ecosystem services in the Nordic and Baltic landscapes" and CAR-ES III "Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems". Through this activity, more case studies were presented and made available for the work of this report (see Annex II).

Some of the case studies are being developed for publication in a special issue of the scientific journal "Energy, Sustainability, and Society", under the heading "Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes", as reports under IEA Bioenergy Tasks, or as manuscripts intended for other journals. They are in various stages of completion, from manuscripts in progress, to those under review and revisions and those already fully published. As this synthesis report sought for patterns across all case studies, reference is being made to manuscripts, papers, and reports in all stages of publication. This report should thus, to some extent, be seen as preliminary work and conclusions. Additional case studies will also become available as the special issue progresses.

It is our sincere hope that this report will contribute to a conscious integration of sustainability governance with efforts to deploy bioenergy opportunities for societies' movement towards a more sustainable development.

Summary

Sustainability governance is a means to resolve alternative perspectives on what goals and practices can be regarded as sustainable. To be successful, it is critical that the governance measures hold a high level of legitimacy. Theory on legitimacy suggests that this can be achieved through actors' participation and involvement in the governance system (input legitimacy), ensuring success of the governance system in what it attempts to achieve (output legitimacy) and administrative and economic efficiency in implementation and enforcement (throughput legitimacy). In spite of the efforts made to create effective, efficient legitimate systems, these are often subject to criticism. It remains as question what is needed to increase trust in these systems. Innovation policies for renewable energy are desirable for a transition to a movement towards more sustainable societies, namely reduction of greenhouse gas emissions. At the same time it is crucial that other sustainability goals are duly regarded.

Careful analysis is an important basis to identify the best combination of renewable and bioenergy policies policies, with regard to their effectiveness, efficiency, political and social feasibility, as well as balancing these with any undesirable economic, environmental and social impacts. Sustainability governance to protect against undesirable impacts tends to emerge with various time lags compared to developments evoked by renewable and bioenergy policies, depending on the mechanisms in place to identify them. Such time lags may be critical to the realization of the opportunities offered by bioenergy if public support for bioenergy policies vanishes when concerns are not addressed.

Careful analysis and assessment is needed to identify the most effective, efficient and legitimate sustainability governance design. This requires tailoring to the owner types and structures and culture in each region or country, when putting in place a mix of mandatory and voluntary, incentivising or command and control approaches, prescriptive or less prescriptive requirements, and management unit level or risk-based approaches to verification. Any verification systems will rely on formalised or informal assessment of risk. In order to increase transparency, we suggest movement towards formalisation of risk assessment elements.

Considering the complexity of all interactions, high levels of uncertainty, and the speed with which conditions can change in unpredictable ways, due to introduced policies or other dynamics in society, it is important to continuously monitor and assess the renewable energy policies and sustainability governance against agreed criteria and establish platforms for stakeholder communication and exchange of experiences. These tools should be embedded in adaptive governance frameworks, where policies as well as the criteria against which they are assessed are continuously revised according to observed impacts, developments and changes in values. This also includes adjustment of financial incentives when necessary, or discontinuation of these, when they are no longer needed.

Special concerns arise for international supply chains. In this case, the private bioenergy and certification sector plays a distinct role in the development and implementation of sustainability governance systems, while governments are important for providing the overall sustainability frameworks. Special attention is required to mitigate the democratic deficiency of such policies in third countries, especially when the voice of less powerful local actors is not heard among more well-organised, powerful or charismatic international profit optimising and non-profit organisations.

Since bioenergy is not an island, it is also important that governance systems and associate monitoring systems and assessment methodologies include the larger sectors to which bioenergy development is linked, for example agriculture, forestry, waste handling, nature conservation. As

a basis sustainability governance innovation to address these issues, we suggest that the potentials of a diverse range of emerging landscape and regional approaches to governance are explored, and that consistent information about biomass flows from production in the field to end-of-life should be collected, including traditional and novel bioeconomy products as well as bioenergy, re-use and recycling should be established. Such information is critical to holistically assess climate impacts of bioenergy in the context of the larger sectors.

Considering challenges with creating trust in sustainability of bioenergy, which are due to misunderstandings and misapprehension, or biased and unreliable information, rather than legitimate concerns, we consider that carefully designed, and impartially implemented and enforced bioenergy policies combined with carefully designed sustainability governance systems are a necessary basis ensuring sustainability of bioenergy practices, as well as building trust in these practices.

1. Introduction

1.1 INCREASING USE OF BIOMASS FOR BIOENERGY AND THE BIOECONOMY

Bioenergy has been a main source of energy for mankind before industrialization. From this point, the use of fossil fuel gradually increased and had entirely replaced biomass in many countries by the 1960s (Erb et al. 2008, Stupak & Raulund-Rasmussen 2016). After the oil crisis in the 1970s, the use of bioenergy gradually increased again in many of the same countries, as it was less costly than fossil fuels. Also, supplies were more secure. After the UN Earth Summit in Rio in 1992, the mitigation of climate change increasingly became the motivating factor for production and use of bioenergy, due to its potential to displace fossil fuels.

Biomass is also increasingly being considered as a substitute for other raw materials, under the concept of the bioeconomy, or biobased economy. Since the mid-2000s, the bioeconomy has emerged as a key concept for solution to multiple major societal challenges (Bugge et al. 2016). Patermann & Aguilar (2018) see four common denominators of activities captured by the bioeconomy concept: they are renewable, carbon-friendly, they exhibit circularity, and they may offer new additional and better functions, such as larger stability, longer lifetime, less toxicity, less resource consumption, and increased sustainability. Bioenergy is often seen as part of the bioeconomy.

1.2 SUSTAINABILITY OF BIOENERGY UNDER SCRUTINY

As bioenergy production and use has continued to grow in the last decades, the sustainability of bioenergy has been seriously questioned by some groups, while other organizations worked to make bioenergy a part of the solution for a more sustainable future (May-Moulin et al. 2019, Sutor et al. 2019). Such questions are also emerging more generally for the bioeconomy. The costs and benefits of especially bioenergy are now more contentious than ever, and the potential contributions of bioenergy and the bioeconomy will hardly be realized until consensus is reached on which practices could be considered as sustainable and how to address the risks. Such agreement is a precondition for skeptical societies and individual groups to grant trust to the institutions and organizations promoting bioenergy, so that they can implement agreed-upon sustainable practices (Fig. 1).

Figure 1. A simple model of agents' striving to achieve the trust of the principals, and principals' granting of trust to the agents.

Any agreement will rely on the stakeholders' willingness to make compromises and support scientific evidence. All parties must stay focused on **operationalizing the concept of sustainability and finding pragmatic solutions**. However, it is also important to recognise that opinions on what is sustainable will always differ, and the process must not freeze due to insatiable demands for proof of no risk for any sustainability issue.

Special opportunities and challenges arise from the increased use of social media. They offer great opportunities for wide distribution of information, but they are also effective means to spread simplified or even twisted information, intentionally or unintentionally. Once a statement becomes viral, regardless of how false it may be, some will be convinced about its truthfulness, and it may take enormous resources to counter the misconceived perceptions, if at all possible. As expressed by Hendricks and Hansen (2016), p. 253: "What is viral is not necessarily true, and what is true does not necessarily go viral. Maximizing votes does not require facts, no matter how much we would like it to be so, but then again, voter maximization does not add up to democracy. If democracy doesn't have access to reliable sources of information and doesn't respect valid argument, then there is no way to distinguish between junk evidence and facts. Without the ability to make this distinction, we may be welcoming the post-factual democracy."

1.3 SUSTAINABILITY GOVERNANCE TO CREATE TRUST

Sustainability governance is a means to resolve alternative perspectives on what goals and practices can be regarded as sustainable. In the current context, we understand **sustainability governance** as the **set of regulatory processes and mechanisms by which governments and organizations seek to influence the sustainability of other actors' actions and their outcomes**. To be successful, it is critical that the governance measures hold a high level of legitimacy. Theory on legitimacy suggests that this can be achieved through actors' participation and involvement in the governance system (input legitimacy), ensuring success of the governance system in what it attempts to achieve (output legitimacy) and administrative and economic efficiency in implementation and enforcement (throughput legitimacy) (Mansoor et al. 2019). Several governance mechanisms have been developed to address sustainability issues in different sectors, including bioenergy. In spite of the efforts made to create effective and efficient systems with high degree of democratically developed substance and participation, these systems are often subject to criticism.

1.4 AIM

This paper aims at examining how the legitimacy of sustainability governance systems for bioenergy and the bioeconomy can be improved to increase levels of trust among stakeholders, thereby furthering theory on sustainability governance. Case studies of local and international bioenergy product supply chains from forest, agricultural or side-stream and waste biomass were analysed to provide evidence in support of new hypotheses on how input, output, and throughput legitimacy can be improved. A special focus was on how data and scientific knowledge may help.

2. Methods

2.1 CASE STUDIES

This study is based on a number of case studies of three overall bioenergy and bioeconomic supply chains, with a focus on use of 1) **wood for production of heat and power**, 2) **agricultural**

biomass for production of transportation biofuels and biomass for the bioeconomy, and 3) **residue and waste biomass for production of biogas** to be used for heat and power or transportation. The case studies originate from different parts of the world (Annexes I and II). For some of the addressed supply chains, feedstock production and energy product end-use take place nationally, while other supply chains involve international trade. The different supply chains are at different stages of market development. Some are only being discussed or planned, but have not taken off, while others are emerging, or being commercially scaled up. Yet others have existed commercially for decades.

2.2 ANALYTICAL APPROACH

Case studies were reviewed with focus on the involved agents and principals, the role of different policies as drivers or inhibitors of bioenergy deployment, the types of associated sustainability policies and their designs and the degree to which these systems achieve their goals. The overall purpose was to identify patterns across case studies, which could help to understand the importance of policy design for the effectiveness of sustainability governance systems.

An analytical procedure was created for the individual case studies with the following components.

1. Basic description of the chosen bioenergy or bioeconomic supply chain, its scale and context, for example the political, social, economic, technological, or biophysical context, as relevant.
2. Review of the most critical sustainability issues, including sustainability benefits and challenges.
3. Analysis with classification of policy approaches to the sustainability issues identified in (2).
4. Estimation of the administrative and economic burdens associated with the studied sustainability governance system.
5. Review documentation available for demonstrating the compliance with the governance system and its effectiveness on the ground.
6. Review of communication strategies used in the governance system.
7. Identification of the relationships between policy approaches, documentation of compliance and effectiveness, the administrative and economic burdens and the perceived legitimacy of the governance system.
8. Summary of lessons learned and discussion of opportunities to improve legitimacy of the studied sustainability governance system.

The eight-step procedure was adapted and adjusted to each case study, as needed. The policy analysis was supported by information about which actors that developed the system and their relationships with one another. It was also recognized that governance systems develop through different phases, and that stakeholders' granting and achievement of trust may develop through those phases. Finally, it was also acknowledged that the level of trust and legitimacy associated with a certain system could be linked to the design of governance systems, for example if it is mandatory or voluntary, prescriptive or less prescriptive.

Terminology and approaches for analyzing sustainability governance systems for bioenergy are discussed by Mansoor et al. (2019), providing definitions for sustainability, sustainability governance, legitimacy and trust.

3. Governance for bioenergy deployment

One might ask to what extent the bioenergy sector needs policies or a free market to develop, and how these policies should be designed for cost efficient and effective deployment.

3.1 INTRODUCE POLICIES FOR MARKET TAKE-OFF

Several of the case studies showed that development of bioenergy markets is linked to governmental policies, which confirm earlier findings (Smith et al. 2016). Such policies include financial incentives, bioenergy mandates, and tax exemption, sometimes supplemented by support for investment or research and development (R&D). Policies were thus supportive of the development of the biogas sectors in Germany (Thrän et al. 2019) and Denmark (Al Seadi et al. 2018), and the agricultural biomass-based biofuel sector in the U.S. (Gan et al. 2019) and use of straw for energy in Denmark (Bentsen et al. 2017, Bentsen et al. 2018, Bentsen et al. 2019a, Bentsen et al. 2019b). Policies also supported the development of forest biomass-based heat and power production, based on various combinations of domestic or imported resources. Sweden, Finland, and Austria have well developed forest-based bioenergy sectors mainly based on domestic resources (Koponen et al. 2015), while for example Denmark (Larsen et al. 2019) and Japan (Kitigawa 2018) are increasingly importing wood fuels to supplement domestic production. Finally, forest-based bioenergy is largely dependent on imported wood pellets in the UK and the Netherlands (Stupak & Smith, 2018), with expected increases in imports in the future. **In cases with no or weak policy incentives, the development of bioenergy markets had not yet taken off**, for example in the case of cellulosic transportation biofuels from agricultural feedstock in Canada (Lalonde & Wellisch, 2019, Littlejohns et al. 2018), the U.S.A. (Gan et al. 2019, Nair et al. 2017, Nair et al. 2018, Nair et al. 2019, Hartley et al. 2019) and Denmark (Bentsen et al. 2019b), or forest biomass-based bioenergy in Canada (Cheung & Smith 2019, Littlejohns et al. 2018) and Norway (Hansen et al. 2019). Even if bioenergy production systems were sometimes invented and started by innovative frontrunner entrepreneurs, our analysis suggests that these practices and systems will generally not be scaled up until government policies are put in place.

3.2 APPLY ADAPTIVE FRAMEWORKS TO ADJUST POLICIES

Policies were also found to be important drivers **in later stages of market development**. Thrän et al. (2019) categorised actions to govern the development and sustainability of the German biogas sector according to four phases of market development, as described by Heuss (1987), including the (1) **introduction phase**, (2) **expansion phase**, (3) **maturing phase**, and (4) the **stagnation phase**. The introduction phase is characterized by no or small markets, a need for a significant level of investment and high risk with regard to future profits, high costs and small profits, and, possibly, high prices and limited competition. The expansion phase is mainly characterised by increasing competition, changing marketing strategies, reduced cost, decreasing prices, and increased profits. The maturing phase is defined by a peak in sales, decreasing market shares and ongoing reduction in production costs. The stagnation phase finally sees a drop in sales and profits, with a need for substantial innovation and cheaper production. Thrän et al. (2019) found that the development of the German biogas sector was closely linked to government policies through the different phases. However, we also found evidence that policy development may interfere with the expected trajectory of market phases. For example, the development of the biogas sector in Denmark stagnated in the expansion phase when policy support declined, but took a second leap forward again when policy support was restored (Al Seadi et al. 2018).

This differs from development of free markets that emerge as a consequence of research, innovation, and profit generating opportunities for private and public investors. However, it is in agreement with other authors concluding that success with this long term renewable energy project **requires a stable political framework, and a well-tailored financial, technical and administrative support system** (Fouquet 2013). It is important to notice that this is not a special feature of the bioenergy sector, or renewable energy. Other development in other sectors and industries depend on financial policy support as well, including the fossil fuel industry (OECD 2018a, Shelbaya 2015), and the agricultural sector (OECD 2018b) in several countries. However, examples from the energy and other sectors show the importance of continuously monitoring and assessing the situation against agreed criteria in an adaptive framework (Fig. 2), in order to avoid failures by timely adjustment of financial incentives when necessary, or discontinue these when they are no longer necessary (Thrän et al. 2019).

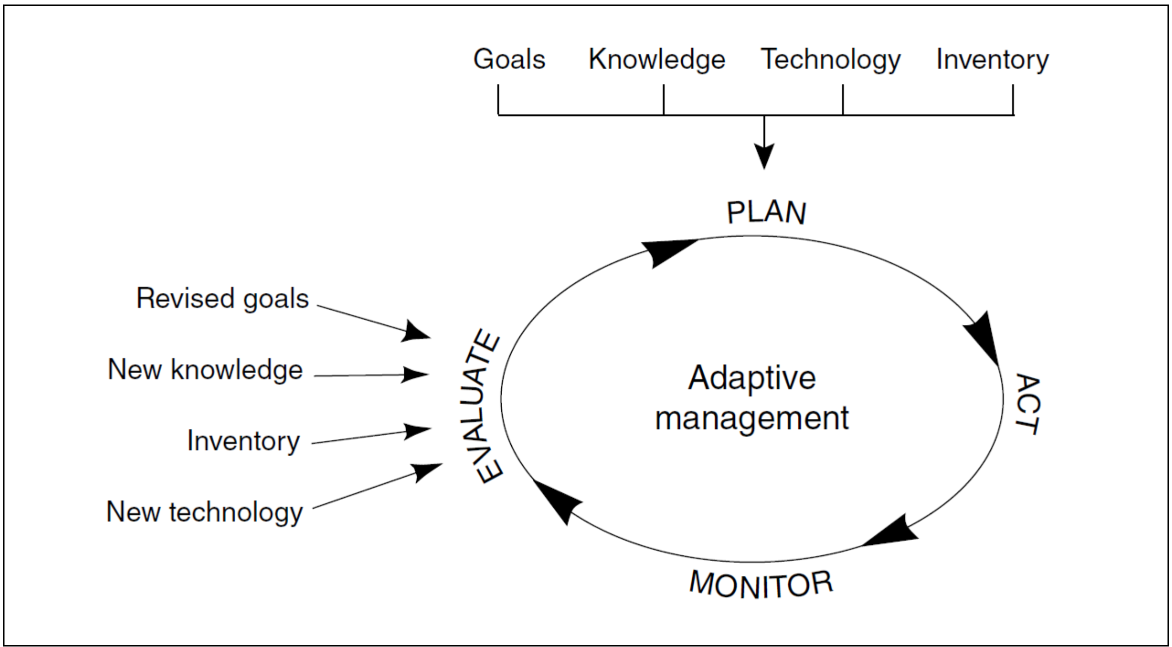

Figure 2. The adaptive management circle (Stankey 2005).

3.3 ASSESS WHICH TYPES OF POLICIES ARE DESIRABLE

Recognizing that policies have been critical to bioenergy deployment and development in several cases, the next question concerns which policies are most cost efficient on one hand, and effective in achieving their goals on the other hand (Purkus 2016). The used approaches differ among countries. The most important policy instrument to promote renewable electricity production in Sweden is the electricity certificate introduced in 2003 (Ministry of Sustainable Development 2006). This system is technology-neutral with priorities for cost-efficient renewable electricity solutions, rather than promoting one technology over the other. Other countries have chosen to apply technology-specific approaches, for example Germany (Gawin et al. 2016) and Denmark (Bentsen et al. 2017). Gawin et al. (2016) provides three arguments for why technology-specific support schemes may sometimes help to minimize the societal costs of reaching renewable energy targets: (1) inability of technology markets to improve future cost performance, (2) the inability of financial markets to overcome obstacles to long-term risk-taking, and (3) no regard to externalities. **It will be context specific which type of governance approach is most desirable, depending also on priorities and preferences of agents and principals of the relevant society.** The question requires careful analysis and discussion in each case (van den Bergh et al. 2011).

4. Efficient and effective sustainability governance

It is questionable how governance can best address sustainability concerns associated with bioenergy practices, and thereby build legitimacy and create trust in the practices being implemented. Assuming that sustainability governance is critical to create trust in the long term, it is a question how such systems should be developed, designed and implemented to be cost efficient on one hand, and effective in achieving their goals on the other hand.

4.1 APPLY ADAPTIVE FRAMEWORKS FOR TIMELY ADDRESSING OF SUSTAINABILITY CONCERNS

Case studies suggested that sustainability concerns, other than those promoted by bioenergy policies, are identified and addressed with various **time lags** from the introduction of bioenergy practices. This is a symptom of an underlying problem; we cannot expect to predict all consequences of bioenergy or any other human activity, as we are dealing with complex systems. However, the length of the time lag will depend on the mechanisms in place to identify potential challenges.

In the very early phases of development of manure-based biogas in Denmark, governance of sustainability issues relied on existing policies and governance for the larger sectors such as energy, agricultural crop and livestock production, waste handling, environmental protection and nature conservation (Al Seadi et al. 2018). Soon after, biogas practices were continuously challenged and reshaped through the interaction and exchange of experiences among actors in the biogas sector. The aim of these processes was to effectively promote the potential benefits and address the potential challenges of the manure-based centralized biogas concept. In the case of biogas in Germany, governance was continuously challenged and reshaped through integrated governmental monitoring programmes. For forestry in Canada, an adaptive framework has been developing since the mid-1990s through various phases of forest policy development (Koven 2015), with rigorous frameworks that require revision of mandatory guidelines for sustainable forest management in regular 5-year intervals (Cheung & Smith 2019, OWNRF 2010). **As markets develop, challenges may be identified** by either measurable threats, by forecast assessments, or through new scientific knowledge. If an **adaptive framework** is applied, this **will support timely adjustment of measures to promote opportunities and mitigate undesired impacts as they emerge** (Fig 2).

Apparently, there was an exception from the overall pattern that sustainability governance comes with a time lag. Forest biomass harvesting and wood ash recycling guidelines have been developed in several jurisdictions without substantial development of bioenergy markets (Titus et al. 2019). Perhaps near-term market opportunities were foreseen, but further analysis is needed to identify the drivers in these cases.

Apart from communication platforms and adaptive systems, there are also examples of governance being reshaped in response to changing societal needs and priorities. In Sweden, for example, the main goal of the Forestry Act through the first half of the 20th century was to protect the forest against degradation after hundreds of years of overutilization (Lindahl et al. 2017). After World War II, the focus changed to acquiring raw materials for a booming wood industry, until the UN Earth Summit in Rio in 1992, when the focus changed again, to include consideration of several environmental objectives in managed forests.

4.2 APPLY CO-REGULATION FOR INTERNATIONAL SUPPLY CHAINS

Additional sustainability concerns for unsustainable bioenergy practices have emerged in the last decades due to increasing imports of liquid biofuels and wood fuels in several European countries. Major concerns include the risk of deforestation and forest degradation, conversion of natural forest to plantations, and intensification of the management and harvesting, with potential impacts on ecosystem carbon stocks, biodiversity, soil and water (Stupak & Smith 2018).

Deforestation is a well-documented challenge in the land use sector, especially in tropical countries (Curtis et al. 2018). The EU Forest Law Enforcement, Governance and Trade (FLEGT) regulation (European Union 2005) was adopted to address concerns for deforestation in tropical countries. Fifteen countries that supply more than 80% of the EU's tropical wood are now in different phases of implementing Voluntary Partnership Agreements (VPA) with the EU under FLEGT (FLEGT 2019). Private governance approaches to challenges in tropical countries include certification systems, such as the Roundtable for Sustainable Palm Oil (RSPO) (Goh 2016) and various novel landscape approaches (van Dam & Diaz-Chavez 2019). In the case of wood pellet production in the Southeast US for European markets, several publications have been published to explore and inform about the impact of bioenergy practices on forests (e.g., Dale et al. 2017, Parish et al. 2017, Kline et al. 2018). These publications document that overall deforestation is limited in the Southeast US, and it occurs mostly due to urban development. The afforestation area is of the same magnitude as the deforestation area in this region. In Europe, there is even a net gain in forest area (Fuchs et al. 2013).

Sustainability concerns may thus be justified or arise due to little knowledge or understanding of sustainability and sustainability governance in sourcing areas. The risk of such **misunderstandings are larger for international supply chains**, where stakeholders and customers are separated from biomass production, not only by long distances, but also in terms of institutional, societal and cultural differences. There is a **call for unbiased information**, which is not always available from widely used social media (Mai-Moulin et al. 2019).

The overall level of concern has led to additional layers of public and private sustainability governance being adopted and implemented by the energy sector, especially in the EU and member states (European Union, 2009, European Commission 2016). These systems fall under the category of so-called co-regulation (Cafaggi 2006) or transnational regulation (Fig. 3), and rely on **private certification for showing compliance with EU and national legislation and agreements** (van Dam et al. 2012, Stupak & Smith 2018, Larsen et al. 2019). Certification systems rely on several information sources, including regional and national monitoring systems and datasets, which provide valuable information for identification of different impacts (Dale et al. 2017, Parish et al. 2017). They usually include elements of adaptive management, which help to ensure timely adjustment of practices when needed (Raison 2002, Lattimore et al. 2009, Mead & Smith 2012).

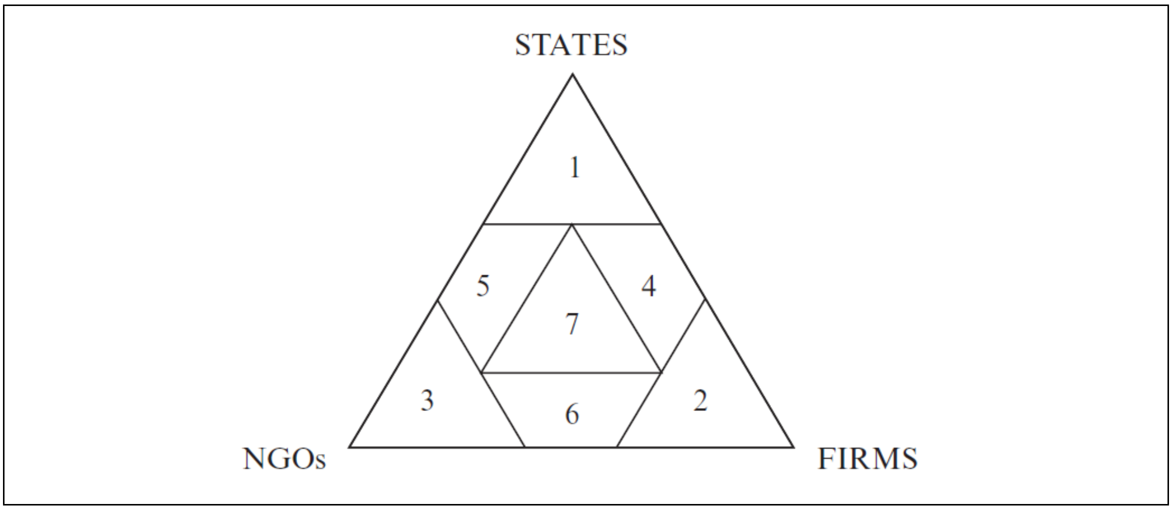

Figure 3. "The governance triangle" with seven governance categories: (1) traditional top–down legal standards, typically laws; (2) self-regulation; (3) third-party private regulation; (4) standards of firms influenced by states (co-regulation); (5) standards of NGOs influenced by states (co-regulation); (6) joint efforts between firms and NGOs; (7) joint efforts between firms, NGOs and states (transnational regulation) (Mansoor et al. 2016, redrawn after Purnhagen 2015).

Previously, the private sector was only reluctantly subjected to sustainability governance, but trust and transparency is becoming just as important to corporate reputation as the quality of products and services (2015 Edelman Trust Barometer). Suppliers and consumers, for example wood pellet producers and power plants, share a common interest in assuring adequate sustainability governance systems so that their businesses can continue to develop. In the case of wood pellets, the private energy sector has even played a leading role in establishing standards that go beyond legal requirements (Mansoor et al. 2016, Larsen et al. 2019). This is also the case for food production in Canada (Lalonde & Wellish 2019), and sometimes other production systems in tropical conditions (van Dam & Diaz-Chavez 2019).

4.3 ASSESS IF MANDATORY OR VOLUNTARY APPROACHES ARE EFFICIENT AND EFFECTIVE

There is generally a call for mandatory regulations with high degrees of **prescriptiveness** by NGOs and environmentalists. It seems intuitive that prescriptive and strict requirements are more effective for achieving sustainability goals, and thus more legitimate and trustworthy compared to voluntary regulation. However, an inherent conflict is built in. McDermott et al. (2010), p. 342, explains this in the following way: "On the one hand, there is widespread civil society demand for prescriptive regulations to ensure consumers through complex and diverse global supply chains. Call for greater prescriptiveness stem in part from the recognition that without precise, standardized requirements, it will be difficult for stakeholders and customers in distant markets to have any assurance of the level of environmental practices followed. On the other hand, there is increasing recognition by many of the same actors and practitioners, that **locally based decision-making is needed** if forest management is to be appropriately **tailored to current and (changing) local environmental and social conditions**. Yet, the greater the prescriptiveness at the national, state or provincial levels, the less room is given for local field-based discretion". McDermott et al. (2010) consider this conundrum to be one of the greatest challenges facing sustainable forest management today, and this applies equally to agricultural management and bioenergy feedstock production.

Case studies indicate that the solution to this conundrum has been a **mix of mandatory and voluntary, public and private, and incentivising and command and control approaches**. However, there are significant variations in the mix of policy instruments being used, for example in forest management. Canada and most of the former socialist countries in Europe focus more on public regulations and rely on command and control instruments (Cheung & Smith 2019, Nichiforel et al 2018, McDermott et al. 2010), while US and Western and Nordic European countries use less prescriptive legal frameworks and focus more on voluntary market-based approaches (Kittler et al. 2019, Larsen et al. 2019, Nichiforel et al. 2018). There are similar differences for bioenergy based on agricultural biomass, with Canada (Lalonde & Wellisch 2019) and the US (Gan et al. 2019) relying more on voluntary approaches, while member states of the European Union to a larger extent rely on mandatory regulation (Bentsen et al. 2019b). However, there also seem to be differences within Europe, with the biogas sector in Denmark being governed by voluntary instruments for several issues (Al Seadi et al. 2018), while the biogas sector in Germany seems to be governed by legislation (Thrän et al. 2019).

As indicated by McDermott et al. (2010), a special challenge arises for international supply chains with large distances between producers and customers, for example in the case of wood pellets from North America to the EU (Kittler et al. 2019, Stupak & Smith 2018), and transportation biofuels from North and South America to the EU (Gan et al. 2019, Bentsen et al. 2019b). It is **not possible to implement mandatory, prescriptive regulations in third countries**, but governments seek to influence the sustainability or practise in third countries in other ways, for example bilateral VPAs under EU FLEGT (EU 2005) and co- or transnational regulation under the EU Renewable Energy Directive (2009) (Fig. 3). It means that **private certification schemes** are accepted for showing compliance with EU requirements (Mansoor et al. 2016). Actors, also in third countries, must thus apply these voluntary systems in order to gain access to bioenergy markets in Europe.

4.4 MOVE TOWARDS FORMALIZED RISK-BASED APPROACHES TO VERIFICATION

The EU Renewable Energy Directive (2009) includes selected key sustainability requirements, especially environmental requirements, with private certification systems verifying compliance at the farm level, in principle. However, the Directive's verification requirements are relatively generic, and self-declarations, desks audits and risk assessments are partly used in some systems (van Dam et al. 2012). EU wide sustainability criteria were also adopted for forest biomass in the revised EU Renewable Energy Directive II (2018), which will come into force from 2021. In this case, **national risk assessment** is the main approach **to verify criteria for sustainable forest management**. In risk-based systems, the verification of sustainability consists of risk assessment of the sourcing area, the region or the country. The risk assessment is conducted as a desk audit (Fig. 4). For indicators assessed with specified risk, on-the-ground mitigation measures are implemented to document low risk or change practices to achieve low risk. Certification systems that use national and regional risk assessments, such as the Sustainable Biomass Program (SBP) (SBP 2019), are already accepted as documentation by current national schemes in some EU member states, for example the UK and Denmark (Stupak & Smith 2018, Larsen et al. 2019). In the Dutch SDE+ Scheme (2019) to stimulate sustainable energy production, risk-based approaches are temporarily accepted for small forest management units (<500 ha) in a 2-5 year period after the starting year of the SDE+ subsidies. However, when grants approved in 2020 end in 2022, the verification of the SDE+ sustainability criteria must be based on certification at the forest management unit level for all forest biomass.

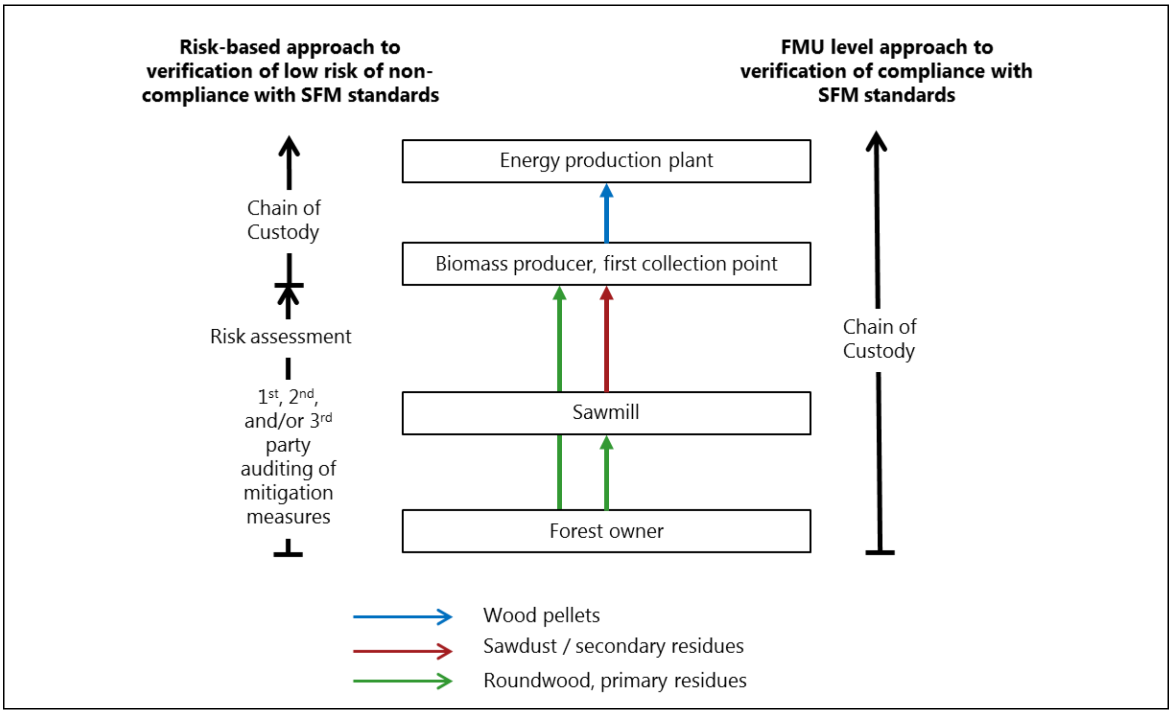

Figure 4. Illustration of the difference between verification at the forest management unit (FMU) level and a risk-based approach to verification of sustainable forest management (SFM) in a wood pellet supply chain (Stupak & Smith 2018).

4.5 CONDUCT RESEARCH TO IDENTIFY APPROACHES DESIRABLE IN DIFFERENT CONDITIONS

It is not yet known whether sustainability goals can be achieved more effectively through mandatory or voluntary approaches, incentives or command and control approaches, or prescriptive or less prescriptive requirements or guidance (Fig. 5a). Case studies do not immediately suggest a clear relationship for forest-based, agriculture-based or biogas supply chains. This is in agreement with a comprehensive study by McDermott et al. (2010) on forest legislation from different jurisdictions around the world.

A clear relationship is also not seen when approaches have changed over time. Sweden has for example seen a change from prescriptiveness and strict regulation to protect forests against degradation in the first half of the 20th century and even more comprehensive and prescriptive regulation after World War II to ensure wood raw material production, to deregulation in the early 1990s with additional mandatory environmental goals, but greater flexibility in terms of how to achieve these (Lindahl et al. 2017). An explanation for deregulation processes that also took place in other countries (Nichiforel et al. 2018) might be the increasing complexity in set of goals to be achieved. **Multiple goals make it more complicated to regulate prescriptively**, especially when these are inter-related and potentially conflicting in a site-specific manner. The risk of encountering unintended effects in such a situation is probably high.

It is also not yet known whether sustainability goals are achieved more effectively through management unit and group level or risk-based approaches to verification (Fig. 5a). Forest management unit level certification also involves some level of risk assessment, since there is not enough auditing time allocated to check all indicators of the forest management standards. In this case, however, the procedure is not formalized and it depends on the individual auditor. Based on conversations with certification auditors, we suggest that the **effectiveness of the certification**

will depend more on the time and resources put into auditing and implementation of required mitigation measures or corrective actions, rather than the verification approach as such (Fig. 5b). Broader, rigorous testing of such hypotheses has not yet been conducted, but an example from Romania already shows that the resources used for Forest Stewardship Council (FSC) certification mainly serve to enforce existing rigorous legal requirements (Buliga & Nichiforel 2019).

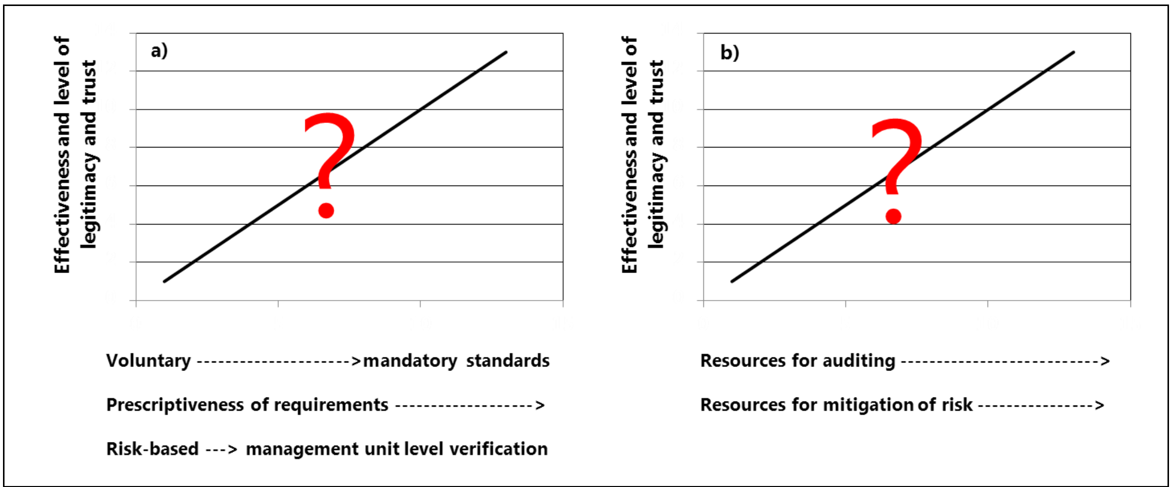

Figure 5. Hypotheses about factors that possibly increase the effectiveness of sustainability governance, and thus its output legitimacy and trust.

4.6 SUPPORT DEVELOPMENT OF DATABASES FOR VERIFICATION AGAINST MULTIPLE STANDARDS

The use of regional risk-based assessments has spurred interest in databases, especially **spatial databases**, with data that can document and monitor the environmental and ecological impacts of the management in a region. Currently, national or regional forestry related risk assessments are conducted to show compliance with the EU Timber Regulation for legality (Due Diligence System, DDS) (European Union 2010), Forest Stewardship (FSC) Controlled Wood (CW) (National Risk Assessments, NRA) (FSC 2019), and SBP certification (Regional Risk Assessments, RRA) (SBP 2019). Some certification bodies, such as NEPCon, handle all three types of risk assessments, as well as forest management unit level certification under FSC and the Programme for the Endorsement of Forest Certification (PEFC). They experience that **databases built for verification of compliance with standards of one system can often be used to show compliance with standards of another system**, as requirements are overlapping (Fig. 6a). For example, all certification standards require legality; FSC CW standards seem to cover about 50% of the SBP requirements for sustainable forest management (SFM) (SBP 2017); Romania has very comprehensive command and control rules for forest management (Nichiforel et al. 2018), and 69% of the Romanian FSC requirements overlap with legal rules (Buliga & Nichiforel 2019). In the Romanian case, the circle representing requirements of applicable national legislation would thus be considerably larger than shown in Fig 6a, and the circle representing available FSC SFM certified biomass would be considerably larger in Fig. 6b, closer to the circle representing available legal biomass. We found no information on the degree to which SFM requirements overlap for the SBP, FSC and PEFC standards and national requirements of the United Kingdom (UK), Denmark (DK), The Netherlands (NL) and Belgium (BE).

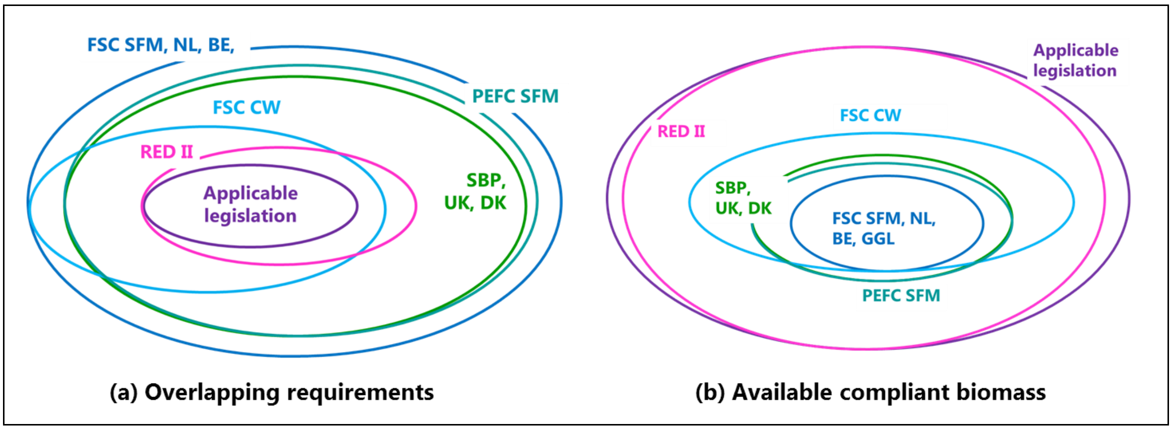

Figure 6. Conceptual figures of how sustainability requirements of different regulations and certification systems might be overlapping (a), and of the impact of requirements on available compliant biomass (b). See the text for abbreviations and further explanations.

New databases and maps are emerging or being developed to increasingly meet the needs for documentation of compliance with public and private regulatory systems. Perhaps the possibility of usage by several systems provides an enhanced incentive to develop them further. With **increasingly advanced technologies available for data collection** (remote sensing, automatic recording from machine-mounted devices, drones, citizen science, real-time monitoring linked to the individual land production units, etc.) and software developed to attribute and process the data, we may see a development in the future that renders certification unnecessary.

4.7 CONSIDER OWNER TYPES AND CULTURE IN GOVERNANCE DESIGNS

Sustainability requirements make it more challenging to mobilise biomass in several countries and regions, especially due to other priorities and inadequate incentive for small forest owners to get certified (Stupak & Smith 2018). Other such challenges may arise from poorly understood priorities and behaviours of new forest owners, especially in Eastern Europe, and new types of owners more generally. Weiss et al. (2019) found that new types of forest owners are emerging due to societal developments, such as changed agricultural structures or lifestyles, or due to polices, such as restitution and privatization policies, mainly in Eastern Europe, land reforms, or changes to inheritance laws. These new types of owners seem to be more passive and absent in relation to the forest management, compared to more traditional types of owners. **Innovative governance systems and instruments are thus needed to engage small land owners**, and probably also new types of land owners, if wood should be harvested and mobilized from their lands.

Legislative command and control measures were effective in mobilizing wood raw materials for the industry in Sweden after World War II (Lindahl et al. 2017). Today, recommendations rather **focus on voluntary measures that motivate forest owners to contribute to mobilization of wood**. Possible measures include access to advice, dedicated education and training, and professionalization of the forest owner, as well as transfer of the management to professionals, or transfer of ownership to active managers, if desired (Orazio et al. 2017). Orazio et al. (2017) as well as Smith et al. (2016) suggested that collaborative efforts will be useful, including joint ownership, joint forest management, cooperatives and joint timber marketing, professionalization of forest owner associations, producer groups, and cooperatives. Legal frameworks are needed to support collaborative efforts, knowledge generation through research, as structures to facilitate collective learning and information exchange, as well as financial incentives. The same measures will likely help to increase the amount of biomass compliant with sustainability requirements according to the standards agreed upon (Fig. 5b).

Efforts to **facilitate forest certification through collaboration** are being undertaken by the Sustainable Forestry Initiative's (SFI) Partner Programs in the U.S. In this region with a small certified area, these programs aim to develop new approaches to group and coordinate certification for medium to large forest ownerships and smaller and medium-sized mills through engagement, education and training (SFI 2019). Voluntary collaborative approaches require build-up of trust and community among the different actors, which takes time (Stupak & Smith 2018). In tropical conditions, a number of new so-called **landscape approaches** are also seeking for new ways to engage with land owners and other stakeholders, to address sustainability challenges related to management of the land base. The term covers a variety of approaches applied at different geographical scales, which are motivated by different underlying drivers, including export commodity production or more local goals (van Dam & Diaz-Chavez 2019).

In a few countries such as Finland and Canada, most of the forest area is already certified at the forest management unit level (Stupak et al. 2009, Cheung & Smith 2019). In Canada this has been possible because of the large share of public ownership. In Finland, the achievement is founded on a long tradition for collaborative efforts such as those described above. However, an assessment of the feasibility of certification in Southeast US and the Baltic states found very little chance that the certified land area in these regions will increase significantly in the short-term, and probably also not in a longer term (Table 1). These regions have a large share of small scale private ownership and different cultural traditions, compared to for example Finland. Certification with risk-based approaches was assessed as more feasible, especially for the current level of wood pellet production, and maybe also a more distant future with increased production levels.

Table 1. Assessment of the feasibility of implementing sustainable forest management (SFM) requirements under the four policy scenarios for wood pellet supply chains based, by 2020 and in the long term (a decade or more) in south-eastern U.S. and the three Baltic countries, Estonia, Latvia and Lithuania, with some differences between these countries that are disregarded here (after Stupak & Smith 2018).

No	Sustainable forest management (SFM) requirements	Chain of Custody requirements	South-eastern US		Baltic countries	
			By 2020	Long-term	By 2020	Long-term
1	Secondary feedstock does not require documentation of compliance with any SFM standard.	From the pellet producer and downstream	****	*****	****	*****
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').	From the pellet producer and downstream + risk assessment upstream from the pellet producer	**	***	****	*****
3	Secondary feedstock requires documentation that it comes from forests with a verified low risk of non-compliance with standards for SFM	From the pellet producer and downstream + risk assessment upstream from the pellet producer	**	***	***	****
4	Secondary feedstock requires documentation that it comes from forests with SFM certification at the forest management unit level	From the forest management unit and downstream	-	*	*	**

- (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).

5. Integrative sustainability frameworks

Policy incentives for bioenergy are often put in place to solve sustainability challenges that relate to management of a 'commons', especially climate change mitigation (Thrän et al. 2019, Al Seadi et al. 2018, Gan et al. 2019 etc.). However, the main goal of initial polices for manure-based biogas in Denmark was to reduce nitrate leaching from agriculture (Al Seadi et al. 2018). In this case, there was a synergy between goals for climate change mitigation and goals to reduce nitrate leaching to adjacent surface waters and groundwater. Such synergy potentially also exists in the case of cellulosic energy crops introduced to otherwise unprofitable fields in the Corn Belt in the U.S. (Nair et al. 2017, Nair et al. 2018, Nair et al. 2019, Hartley et al. 2019) or in Lithuania (Tilvikiene et al. 2019). In the case of manure-based biogas production in Denmark (Al Seadi et al. 2018), the climate and environmental benefits of the bioenergy system were commonly recognized from the beginning. Even if other sustainability issues arose as the sector developed, these were dealt with by continuous development of best practice guidelines by the sector and adjustment of policies. For example, the statutory order on sustainable production of biogas (BEK no. 301) set limits on the use of food and feed crops for biogas production. The environmental sustainability of manure-based biogas has never been seriously questioned in Denmark.

It is a different situation, however, when trade-offs are needed between practices aiming at mitigation of climate change and those aiming at other sustainability goals. However, examples with synergy among different sustainability goals inspire to suggest that **more holistic and integrative frameworks may help to resolve some of the conflict and disagreement around sustainability and bioenergy**. If they transparently make the trade-offs between interlinked sustainability issues, they will likely also be conducive for better understanding the existence of trade-offs and the necessity to make these. Financial incentives for bioenergy are often conditionally linked to land-based environmental sustainability criteria (European Union 2009, European Union 2016, Dutch SDE+ Scheme 2019, Dansk Energi og Dansk Fjernvarme 2016, OFGEM 2019), but trade-offs and major concerns are not always addressed in a transparent and effective way. Hence, innovative solutions are urgently needed to address the most critical trade-offs and concerns in a way that is suitable for governance purposes.

5.1 CATEGORIZE GREENHOUSE GAS EMISSIONS

One of the most critical trade-offs that needs to be made in a more transparent and effective manner is between the greenhouse gas emission savings from different energy sources. In the current frameworks, carbon emissions from biogenic sources are accounted for together with emissions from fossil fuels, even if time perspectives of their impact on climate are fundamentally different. **Biogenic carbon emissions are reversible in the time perspective of years, decades or centuries, while emissions of fossil carbon are practically irreversible at non-geological time scales**.

The most commonly suggested metric seeking to take account of the temporal aspect of climate impacts is carbon payback or carbon parity time. However, this measure can be very sensitive to uncertain assumptions (Taeroe et al. 2017), which is not acceptable as a basis for policy rules. Also, carbon payback times do not address the core of the problem. We suggest that systems to calculate greenhouse gas emission savings for bioenergy instead make a clear distinction between saved emissions from fossil and those from biogenic sources. A distinction could also beneficially be made between more or less carbon-intensive fossil sources, such as coal and natural gas, and biogenic sources with different properties, such as biomass and peat. A hierarchy is needed which prioritizes the reduction of greenhouse gas emissions from the most irreversible emissions and the most carbon-intensive fossil sources, before those from more reversible emissions from biogenic sources, such as biomass.

Such a categorization should consequently group greenhouse gas emissions for both the energy systems with introduced bioenergy and the reference energy system. If the reference system includes other renewables, such as hydropower, wind energy, photovoltaics, and geothermal energy, the emissions from these systems should also be categorized, in principle. However, exceptions might be desirable for these technologies in order to avoid barriers for their development in a transition phase.

5.2 MAKE TRADE-OFF BETWEEN CARBON EMISSION SAVINGS AND CARBON STORAGE

Another critical trade-off that needs to be made more transparently in standards and governance systems is between carbon emission savings from substitution of fossil fuels and carbon storage by ecosystems and in the wood product pool. Policies to reduce greenhouse gas emissions by promotion of renewable energy are typically addressing the energy sector, with no consideration of policies to conserve ecosystem carbon stocks in the land use, land use change and forestry (LULUCF) sector. Carbon storage is instead incentivised through international greenhouse gas accounting systems, with no consideration of the substitution effects in the industry and energy sectors. Calculation methodologies of legislative frameworks, such as the EU Renewable Energy Directives (European Union 2009, European Commission 2016) are also not comprehensive. More comprehensive calculation frameworks have been used in science (Taeroe et al. 2017, Gustavsson et al. 2017), but they are complicated and probably not suitable for governance systems. This challenge is yet to be resolved.

Lack of knowledge about the exact biomass flows, from production in the field, to harvesting, processing, use and re-use for products and energy, and discarding with release of carbon through natural decomposition, is presumably another barrier for transparently making this trade-off (Schulze et al. 2019). Several uncertain assumptions must be made about reference systems for both energy and products. This introduces considerable risk of error and opportunities for manipulation of the results. Again, this is not acceptable as a basis for policy rules. Hence, an urgent priority is to **generate knowledge about biomass material flows from production to its end-of-the-last-life, including all re-use and recycling**. In a next step, a priority must be to create calculation frameworks and standards which include all the relevant impacts across sectors.

5.3 LINK BIOENERGY TO LARGER SECTORS AND LANDSCAPES

Governance systems standards could also create more clarity in the discourse on sustainability of bioenergy if they transparently included sustainability indicators for the impacts of the larger sectors to which bioenergy development is linked. Biomass production for energy is often small compared to the biomass produced for timber and food and often relies on low-value residues or waste from these larger sectors (Dale et al. 2017, Goh 2016, Stupak & Smith 2018). This means that **bioenergy is rarely the driver of the economic activities on the land**. It also means that the economic motivation to certify the management of the land will often come from other sectors than bioenergy. Working towards **uniform sustainability requirements for the whole land base regardless of biomass end-uses** could thus greatly facilitate the implementation of sustainability governance for bioenergy, or basically render it unnecessary.

Case studies show emerging developments towards more holistic governance approaches, which address challenges at a landscape level that: (1) cannot be solved for an individual production unit (van Dam & Diaz-Chavez 2019), (2) are more cost efficiently addressed at a regional level (Stupak & Smith 2018), and (3) focus on promoting bioenergy benefits in a way that recognizes activities in the landscape that serve other goals (Dale et al. 2016). More integrated approaches to governance, which address whole landscapes and regions, might have higher potentials to deal with the land use changes and the joint impact of different land uses and sectors on the commons (van Dam & Diaz-Chavez 2019, Gan et al. 2019).

Such approaches would also have the potential to provide more clarity for complex issues such as indirect land use changes (iLUC), for which confusion in the discourse may or may not have led to lost opportunities. Policy goals for first generation biofuels were put in place to mitigate climate change, for example in the U.S. (Gan et al. 2019), but concerns were expressed that these corn-based biofuels compete for feedstocks and land to produce these (Searchinger et al. 2008). As a result, energy policies in the EU and the U.S. have been adjusted to limit first generation biofuels and increasingly promote second generation biofuels. This led to stagnation or decline of the first generation biofuel sector (Gan et al. 2019, Bentsen et al. 2019b), even if their possible benefits are still being discussed, with some seeing opportunities to mitigate climate change forgone, also in cases where there are probably no negative impacts on the production of food and feed, or where land use changes are rather caused by other factors than biofuel production (Kline et al. 2017). In Germany, a developing biogas sector saw similar challenges, when corn was increasingly grown and used for biogas production. This led to increased competition between corn grown for food and feed and subsidized biogas, and between land for energy corn and grazing in small-scale livestock farming. In this case, an adaptive legislative framework mandated continuous monitoring and adjustment of development. The continuous assessments led to introduction of restrictions on the use of corn and other food and feed crops for biogas. This intervention also legitimized the continued development of the German biogas sector, although in more restricted conditions.

5.4 HOLISTICALLY ASSESS SUSTAINABILITY OF THE RENEWABLE ENERGY SYSTEM

The benefits of bioenergy relative to other renewable technologies are also critical in discussions of bioenergy sustainability. The complexity of the issues and the subsequent lack of clarity may lead to simple rejection of any benefits in any circumstances (Mai-Moulin et al. 2019). However, it is likely that bioenergy can play a beneficial role in a renewable energy system and in relation to other sustainability parameters and development goals (Müller et al. 2015) in some **geographical, economic and social contexts and sectors**, while other renewable technologies might be more beneficial in other conditions and sectors. Sustainability standards and governance should thus clarify to a larger extent if bioenergy is the most economic, environmentally friendly, or socially acceptable renewable energy solution that is available in a specific country, location or supply chain. If all renewable solutions are deemed to be equal in terms of environmental and social impacts, technology neutral incentives for renewables might be preferable. If there are important differences in environmental or social impacts, financial incentives for renewables should favour technologies with the least undesired effects (see also Gawin et al. (2016) for a more detailed analysis). It thus seems desirable to move towards sustainability governance frameworks that include sustainability criteria for the design of renewable energy systems, **based on holistic assessments of economic, environmental and social impacts of alternative renewable technologies and technology combinations**.

6. Recommendations

The aim of this work was to contribute to theory on how legitimacy and trust in sustainability governance systems for bioenergy and the bioeconomy can be increased. Based on evidence found in several case studies, as presented in this report, we summarised our suggestions for actions that might help to increase legitimacy and build trust in sustainability of the bioenergy practices that are finally implemented (Table 2).

Even if these recommendations will not immediately close current significant 'trust gaps', we venture to hope that the suggested initiatives will inspire all parties to further the conversation on what is needed to realise the potentials of bioenergy and the bioeconomy, as a contribution to sustainable development both in the near term and a more distant future.

Table 2. Summary of recommendations on actions that might help to increase legitimacy and create trust in sustainability of bioenergy and the bioeconomy.

LEGITIMATE POLICIES FOR BIOENERGY DEPLOYMENT

- Introduce policies for market take-off
- Apply adaptive frameworks to assess progress and adjust policies to possible new conditions or priorities
- Assess which types of bioenergy policies that are effective and efficient, as well as politically and socially feasible
- Link bioenergy policies to sustainability governance
- Ensure that implementation and enforcement of policies are impartial and keep transparency in value disagreements

Bioenergy practices and systems will generally not be scaled up until supporting government policies are put in place. As **bioenergy sector development seems closely linked to government policies** throughout different phases of market development, success will often depend on stable, long-term political strategies, with well-tailored financial, technical and administrative support systems. However, it is also **important to continuously monitor and assess the situation against agreed criteria**, in order to adjust financial incentives when necessary, or discontinue these when they are no longer needed. Frequent reviews of laws, regulations and other parts of the governance system can help to stimulate involvement of stakeholders, especially in the introduction phase. Types of policy instruments may include financial incentives, bioenergy mandates and tax exemption, sometimes supplemented by support for investment, research and development (R&D), education and training and collaborative efforts. **Identifying the best combination of instruments requires careful and holistic analysis of the effectiveness and efficiency of alternative renewable and bioenergy policies, their political and social feasibility as well as their economic, environmental and social impacts.** Analyses should likewise address which **combination of renewable energy technologies that is most desirable**.

LEGITIMATE SUSTAINABILITY GOVERNANCE

- Apply adaptive governance frameworks for timely addressing of sustainability concerns
- Apply co-regulation for international supply chains
- Assess which governance designs, including mandatory or voluntary elements that are desirable, considering effectiveness, cost-efficiency, land ownership types, culture. as well as the general political and social context
- Move towards formalized risk-based approaches to verification
- Support development of databases for verification against multiple standards
- Ensure that implementation and enforcement of any sustainability governance are impartial

and keep transparency in value disagreements
- Continuously observe new developments in peoples' and societies' concerns to address any changes transparently through involvement, sustainability governance and communication.

Sustainability governance develops dynamically in response to challenges identified in the wake of market development, or due to changes in societal needs and priorities. Sustainability governance tends to emerge with various time lags to address sustainability concerns arising from bioenergy policies, depending on the mechanisms in place to identify them. Such **time lags may be critical** to the realization of the opportunities offered by bioenergy if public support for bioenergy policies vanishes because concerns are not addressed. **Monitoring systems and platforms for stakeholder communication and exchange of experiences and information, embedded in adaptive approaches**, are means to ensure that emerging sustainability concerns are addressed in a timely manner. Special concerns arise for international supply chains. In this case, the **private bioenergy and certification sector plays a distinct role in the development and implementation of sustainability governance systems**, while governments are important for providing the overall sustainability frameworks. **Special attention is needed to the democratic deficiency** of such policies in third countries, especially when the voice of less powerful local actors is not heard among more well-organised, powerful or charismatic international organisations.

Careful assessment is needed to **identify the most effective, efficient and legitimate governance design in a particular context**, for example if this should rely on mandatory or voluntary, incentivising or command and control approaches, prescriptive or less prescriptive requirements, and management unit level or risk-based approaches to verification. Any verification systems will rely on formalised or informal assessment of risk, and in order to increase transparency, we suggest **movement towards formalisation of risk assessment** elements.

In order to be effective, efficient and legitimate it is important that the applied approach to sustainability governance is **tailored for example to the owner types and structures and culture in each region or country**. However, these parameters may also be dynamic and new developments should be observed. Considering challenges due to misunderstandings, and biased and unreliable information about the sustainability of bioenergy, we consider that carefully designed, and impartially implemented and enforced sustainability governance systems are a necessary basis for building trust in the sustainability of bioenergy practices.

INTEGRATIVE SUSTAINABILITY FRAMEWORKS

- Link bioenergy to larger sectors and landscapes in holistic frameworks and to bioenergy policies
- Holistically assess sustainability of bioenergy as part of the renewable energy system
- Use calculation frameworks that transparently show the link and possible trade-off between carbon emission savings and carbon storage
- Categorize greenhouse gas emissions as being of biogenic or fossil origin

Financial incentives for bioenergy are sometimes conditionally linked to land-based environmental sustainability criteria, but especially trade-offs among major concerns are not always addressed in a transparent way. Hence, innovative solutions are urgently needed which are inclusive of the most critical trade-offs in a way that is applicable for governance purposes. We suggest that standards and sustainability governance develops to include the following:

(1) Assessment methodologies to **include the larger sectors** to which bioenergy development is linked, e.g. agriculture, forestry, waste handling, nature conservation, in order to assess the economic, environmental and social impacts of bioenergy in the context of the impacts from these larger sectors. A diverse range of **landscape and regional approaches to governance** are emerging, of which some might be useful for such holistic assessments. We suggest that exchange of experiences and research around these novel approaches is continued to explore their potentials, including their effectiveness, efficiency and legitimacy and ability to build trust.

(2) Assessment methodologies and indicators which can clarify if bioenergy is the most economic, environmentally friendly, or socially acceptable renewable energy solution in a **specific context**.

(3) Assessment methodologies, which transparently and comprehensively include emissions savings from substitution of fossil fuels on one hand and carbon storage by ecosystems and wood product pools on the other hand. These methodologies should also separate or rank emissions along the whole life-cycle according to their reversibility, i.e. typically emissions from **fossil versus biogenic sources**.

(4) Systems to **collect consistent information about biomass flows from production in the field to end-of-life**, including re-use and recycling, and across borders, should be established; such information is **critical to holistically assess climate impacts of bioenergy in the context of the larger sectors**. In a next step, a priority is to create calculation frameworks and standards which include all relevant impacts of the whole systems across sectors, including bioenergy is closely linked.

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