Annual Report 2018

IEA Bioenergy

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IEA Bioenergy is an international collaborative agreement set up in 1978 by the International Energy Agency (IEA) to improve international co-operation and information exchange between national bioenergy RD&D programmes. IEA Bioenergy aims to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use.

Front Cover: Biomass-to-biofuels/briquettes Demonstration Plant, Huazhong University of Science and Technology-Wuhan Optics Valley Bluefire New Energy Co. Ltd., Wuhan, China, recently visited by President Xi.

IEA Bioenergy Chair Jim Spaeth with Paolo Frankl, Head of Renewable Energy Division of the IEA.

To: IEA Headquarters, Paris

IEA BIOENERGY ANNUAL REPORT 2018

Under the IEA Framework for International Energy Technology Cooperation the Executive Committee of each Technology Collaboration Programme (TCP) must produce an Annual Report for IEA Headquarters.

This document contains the report of the IEA Bioenergy Executive Committee for 2018. This year, we have presented a special feature ' Measuring, governing and gaining support for sustainable bioenergy supply chains – lessons and messages from a three-year Inter-Task project', the preparation of which was led by Task 40.

The contributions from the Task Leaders and Operating Agents to this report are gratefully acknowledged.

Jim Spaeth
Chair

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Measuring, governing and gaining support for sustainable bioenergy supply chains – lessons and messages from a three-year Inter-Task project

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Background and aims

Sustainability of bioenergy systems has been at the very core of the IEA Bioenergy Technology Collaboration Programme since a long time, as highlighted in various publications (see for example IEA Bioenergy (2015), Richardson et al. (2002), Berndes et al. (2010), Thiffault et al. 2014). Many of the Tasks under IEA Bioenergy have also focused on aspects of sustainability, most notably Task 38 (Climate Change Effects of Biomass and Bioenergy Systems), Task 40 (Sustainable Biomass Markets and International Bioenergy Trade to support the Biobased Economy) and Task 43 (Biomass Feedstocks for Energy Markets). However, these Tasks typically focused on specific aspects of sustainability, specific technologies, feedstocks or end-uses. A more holistic approach has been lacking, so far.

Also, beyond IEA Bioenergy, several systems to quantify and report on sustainability performance of bioenergy systems have been developed and implemented, for example by the Global Bioenergy Partnership (GBEP 2011); the standard ISO 13065:2015 (Sustainability criteria for bioenergy), and in many non-governmental schemes, e.g. Roundtable on Sustainable Biomaterials (RSB), and the International Sustainability & Carbon Certification (ISCC).

While much has been achieved, there are still challenges associated with understanding, defining, measuring, and assessing sustainability of bioenergy (Fritsche 2019), which are known to be key factors for gaining trust in sustainable bioenergy deployment (IEA Roadmap 2017).

In light of these challenges, the IEA Bioenergy Inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains" was established to extend and synthesise work through collaborative activities involving a number of IEA Bioenergy Tasks, including Task 37, 38, 39, 40, 42 and 43. The project aimed at addressing the following questions:

1. How to assess the sustainability of biomass and bioenergy supply chains?
2. How to improve the input and output legitimacy of existing and proposed governance systems?
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?

The project started in 2016 and was completed at the end of 2018. A multitude of studies have been undertaken, focusing largely on the agricultural, forestry and biogas sectors.

The project created a wealth of deliverables in the form of over twenty predominantly open access papers, workshops, webinars and other outputs. A full overview of all deliverables can be found on the Inter-Task project website (http://itp-sustainable.ieabioenergy.com/iea-publications/).

In the following sections, we present results from a selection of the studies that have been carried out to illustrate how answers to the three central questions were obtained.

- The first case study shows how methods for measuring and quantifying climate and environmental impacts can support implementation strategies where the establishment of new perennial production systems in agricultural landscapes mitigates negative environmental impacts of current land use.
- In a second case study, the importance of governance systems and the role of stakeholders is highlighted for the implementation of biogas plants in Germany.
- Finally, the sustainability of forest bioenergy in Canada is assessed for a biorefinery case study in La Tuque, Quebec, where both the importance of stakeholder expectations and the quantified GHG savings are discussed.

After these examples, we briefly present the key outcomes and lessons learned from the project case studies and briefly outline the continuation of this work in the 2019-2021 triennium.

Assessing ecosystem services to support bioenergy implementation

Society benefits in a multitude of ways from a range of ecosystem services. Some of these are recognised as essential (e.g., food, water and fuels), but several may not be valued unless diminishing. The provisioning of clean drinking water and the decomposition of wastes are today commonly recognised as essential, but may at the same time be taken for granted when available. It can also be difficult to identify causes behind diminishing ecosystem services, the pollination by insects being one example.

Biomass production for bioenergy and the bioeconomy can influence a range of environmental and other values, not least through associated land use change (LUC) and resulting effects on the climate and the capacity of ecosystems to provide ecosystem services. In relation to bioenergy and other biobased systems, one of the key issues is how the systems affect the climate. Most of the studies in this Inter-Task project that address question 1 indeed focus on the climate effects of biomass and bioenergy supply chains. However, we present here results and insights from a study that employed a broader scope, covering a wide range of ecosystem services.

While LUC is commonly perceived as a negative aspect of bioenergy development, there are many examples of how the strategic placement, design and management of perennial grasses and short-rotation coppice and trees can provide biomass for various purposes while enhancing landscape diversity and improving conditions for a multitude of ecosystem services, including enhanced retention of nutrients and sediment, erosion control, climate regulation, pollination, pest and disease control, and flood control. Such beneficial LUC can thereby be effective in mitigating environmental impacts of current agricultural practices, as illustrated in Figure 1.

Figure 1 indicates *those* areas in Europe in which the establishment of new perennial production systems can be more or less effective for mitigating selected environmental impacts. Bioenergy deployment aimed at achieving this objective needs to be based on spatially explicit assessment *within* individual landscapes, which incorporates site-specific characteristics at high-resolution and differentiates between different land management practices.

To support the development of such assessment methods, a systematic review was carried out of methods for analyzing and mapping ecosystem services in landscapes (Englund et al., 2018). Regulating and maintenance services were most commonly mapped (165 cases) in the reviewed studies, followed by cultural (85 cases), and provisioning services (73 cases). For individual ecosystem services, a large variation in number of mapping cases was found. This may reflect the perceived importance of the ecosystem services, and/or that different ecosystem services can be more or less easily mapped.

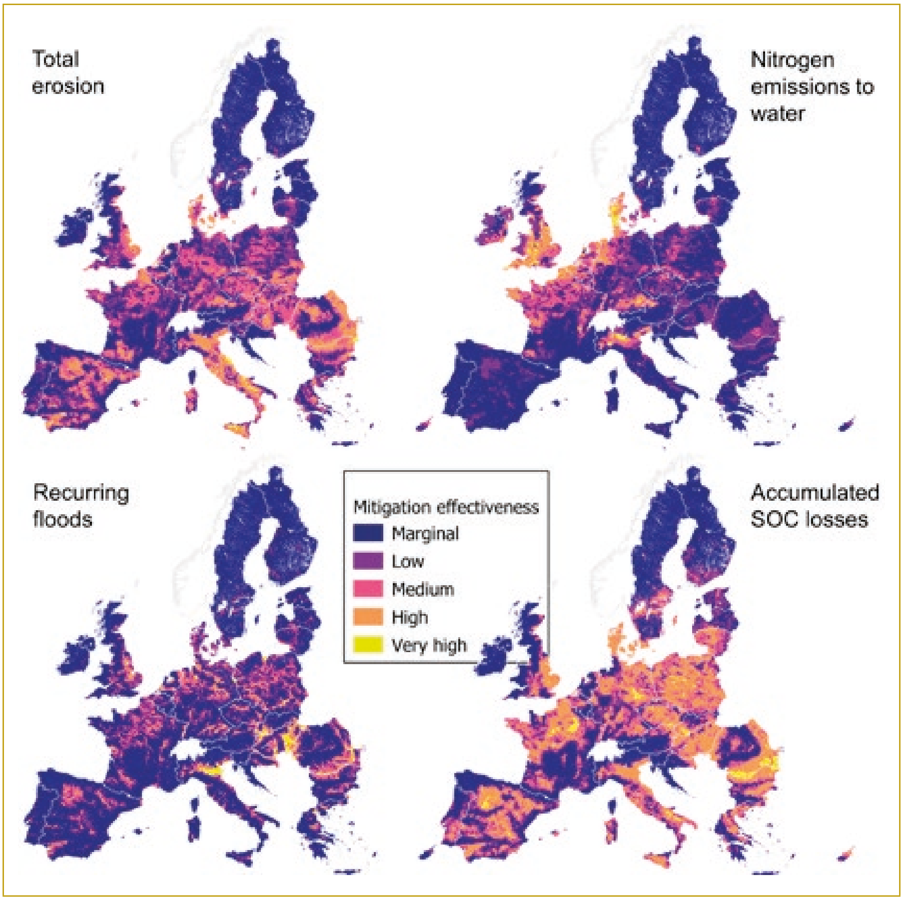

Figure 1: Effectiveness of introducing perennial biomass cultivations to mitigate selected impacts of annual crop production (sub-watershed scale). Source: Englund et al. (in review)

One important finding was that only twelve percent of all cases were validated with empirical data. As unconfirmed results can be difficult to evaluate and thus be of limited use in, e.g., landscape planning, validation should be prioritised in future mapping studies. It is preferable to focus on those ecosystem services that can be studied using meaningful indicators, and are adequately validated. Text box 1 below further summarises related findings from the review study.

Text Box 1. Methods for analysing and mapping ecosystem services in landscapes: main findings

Proxy-based methods are appealing since they are much less complex than, for example, empirical production function models. But there are disadvantages, such as the risk of generalisation error, which can make them unsuitable for landscape scale studies.

Practitioners with advanced GIS skills may benefit from creating their own models. However, some existing models, e.g., the InVEST model, have been applied many times, in several cases with validated and acceptably accurate results. Third-party models should however be evaluated on their suitability for the specific project beforehand, and calibrated and validated using empirical data.

Given the importance of high resolution and need for more complex methods and validation, most assessments with a landscape scope will need to limit the number of ecosystem services included. To ensure that the most relevant services are included, it is essential to involve stakeholders in the selection process.

There is significant diversity in methodological approaches and inconsistent terminology. But there are also harmonisation initiatives, such as the International Classification of Ecosystem Services (CICES) classification system, developed by the European Environment Agency (www.cices.eu).

Translation of ecosystem services into the CICES classification system was in most cases relatively straightforward.

The comprehensiveness and use of more technical terms in CICES may however create a barrier for communication and interaction with those that lack in-depth understanding of ecosystem services. Given the importance of stakeholder involvement in assessments of ecosystem services, this is a clear disadvantage.

It may therefore be beneficial to review the wording or to complement the typology with alternative, less technical, descriptions. This can preferably be coordinated with other initiatives that aim to inform policies and everyday practices, such as the Nature's contributions to people (NCP) concept developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Case study 1 – Implementation of biogas in Germany

Biomass is an integral part of the overall energy system, is used in the chemical industry and is the basis of the worldwide bioeconomy. However, its potential can only be exploited sustainably if biomass is cultivated and governed appropriately. To accelerate the energy transition, there was a need to install governance systems which support the installation of renewable energy plants and also ensure sustainability throughout the bioenergy value chain while maximizing the benefits and minimizing possible negative impacts. The biogas sector in Germany has grown steadily since the enactment of the Renewable Energy Act (REA) in 2000 which aimed to support the energy transition.

This case study investigates how sustainability governance was put into effect with regard to the German biogas market, which is the largest national biogas market worldwide.

The development of Germany's biogas market is structured according to a market phase model of Heuss` to categorise the different development phases (see figure 2). This also allows for transferability of the approach to other countries. Within these market phases, the most important national legislation for market development, the REA (and especially its repeated amendments and associated legislation dealing with sustainability issues) was analysed. Thrän et al. (2019, under review) show that an adaptive REA controlled and steered market development especially through incentivizing energy crops. Implementation of sustainability issues started during the transition from expansion to consolidation. While for greenhouse gas emission reduction, the effects have been monitored and reported for more than a decade, the assessment for other sustainability aspects is diverse. In general, legislation regulating the agriculture sector reacted with a certain delay to the implementation of biogas plants.

Since the early 2000s, the sustainability of bioenergy and biogas in particular is subject to constant scrutiny, especially in the fields of economic and environmental sustainability. However, discussion on sustainability not only takes place in the scientific area but also in the public arena, mainly via traditional and social media. Public concerns about the sustainability of biogas started with the issue of energy crop cultivation for biogas production in the 2010s. To steer sustainability in the biogas sector, a broad variety of regulations and acts were enacted, mainly via top-down lawmaking. However, in order to govern sustainability in every step of the value chain, involvement of numerous stakeholders in the biogas sector is necessary. Therefore, we took a closer look at the involvement of these various stakeholders at different stages of production and consumption of biogas, in order to improve their involvement and nurture an effective future development.

Three steps were initially undertaken for the systematic analysis of the stakeholder landscape, namely: (1) stakeholder identification, (2) stakeholder categorisation, and (3) investigation of stakeholder relationships. In addition, a mapping was performed to identify those actors that most likely affect the implementation of biogas value chains, or are strongly affected by this implementation. These stakeholders were then subject to surveys via questionnaires and semi-structured interviews to gather information on their perception of sustainability governance.

An overview of the interest and influence of different stakeholders towards large scale biogas deployment is shown in figure 3. The results indicate that a large proportion of biogas plants in Germany are situated within agricultural production areas, which is why key players were identified to be farmers and biogas associations, along with environmental NGOs and policy makers. Furthermore, the surveyed stakeholders agree on regulating sustainability at the national level, while tending towards a neutral stance or even disagreeing at the local and international level. They also agree that certification and standards can be an effective tool for verifying compliance with sustainability governance. In conclusion, this study revealed a clear gap regarding management of expectations and in how the current energy legislation (REA) should be transformed to include an all-encompassing bioeconomy.

Therefore, both an adaptive legislation in the energy sector and monitoring elements, which regularly report the environmental effects and the developments in other areas of the agricultural sector (e.g. development of meat production) are needed. Countries implementing a biogas strategy should point out the need for governance where necessary when deciding on the establishment of agricultural biogas. A rapid capacity growth in the biogas sector combined with a significant increase of meat production – and thus fodder production – fostered sustainability threats. It can be concluded that a sustainable development of biogas needs additional instruments; possibly a central one regulating the sustainability aspects of biogas apart from the agricultural sector, but also better implementation of biogas in the further integration into the bioeconomy, i.e. by going beyond the supply of renewable energies.

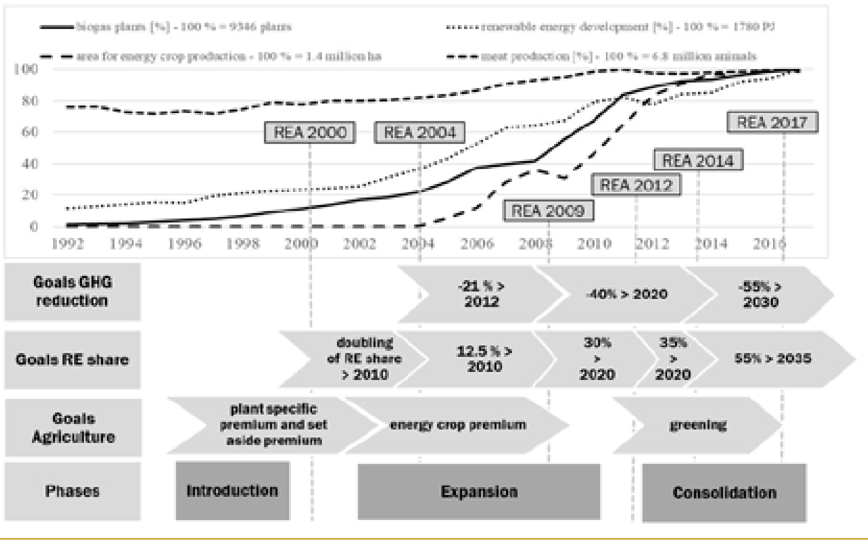

Figure 2 Different Market Phases of biogas sector implementation in Germany Source: Thrän et al. (2019) under review. Data taken from Daniel-Gromke 2017; BMWi 2018.

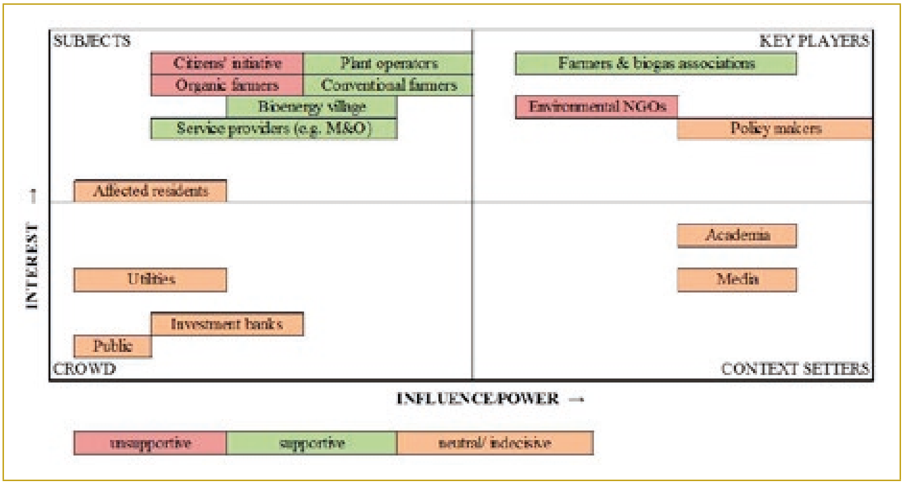

Figure 3. Interest influence matrix of stakeholders (colour-coded to indicate support (green), opposition (red) and neutrality (orange) of large scale biogas deployment); Source: Sutor et al. (2018), under review.

Case study 2 – Sustainability of forest bioenergy in Canada: an example from Quebec

In Canada, the forest sector plays a key role in the social and economic development of hundreds of communities across the country. For example, in Quebec, the current forest industrial network is developed around sawmills and pulpmills. Bioenergy from forest biomass is still nascent, despite an abundance of forest resources across its mostly publicly owned, and largely third-party certified, boreal landscapes.

The municipality of La Tuque, located in the Mauricie region of Quebec, has been working to establish on its territory the first Canadian biorefinery producing biodiesel from forest biomass. Since its foundation in 1909, La Tuque's development has been largely based on hydropower and forestry. However, bioenergy in the form of liquid biofuels represents a new product. The feedstock envisioned for this production would be clearcut harvest residues, which were historically left unused on forest sites or by roadside. The acceptability of such a project within La Tuque, and the willingness of its inhabitants to be actively involved in the establishment and operation of the biorefinery, partly hinges on the local perceptions and expectations towards the future biorefinery.

As a case study towards exploring social acceptability of forest bioenergy in Canada, expectations (both positive and negative) of La Tuque community members (including the general public, stakeholders with various experience and links to the forest sector, and First Nations) towards the planned forest biorefinery, were collected, compared and weighed based on the fuzzy hierarchical analysis process (for details see Thiffault et al., 2019, forthcoming).

The list of collected expectations consisted of 13 statements classified under each of the main criteria of sustainable development, i.e. social, economic and environmental (Figure 4). When ranked and weighed against each other, almost half of the overall weight was attributed to the following expectations:

- Creation of an additional source of income for individuals and companies (economic);
- Creation of new business opportunities (economic);
- Recovering and valuing forest residues of the region (environmental);
- Keeping youth within their communities (social).

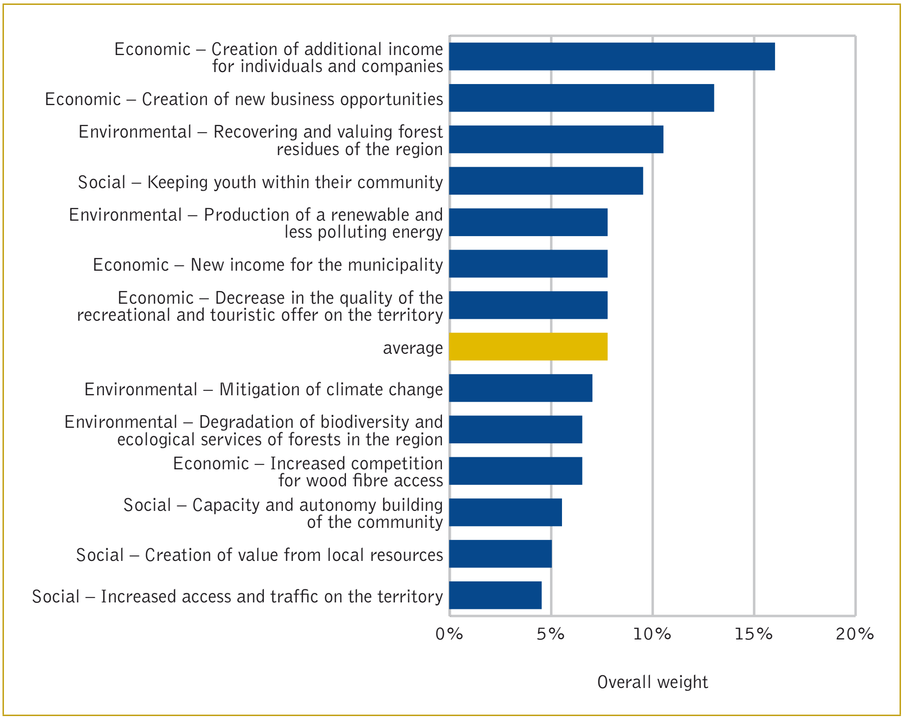

Figure 4: Ranking and relative weight of expectations towards the La Tuque biorefinery. Sum of all weights = 100%. Source: Thiffault et al. (2019).

Four out of the five economic expectations were given an above-average weight relative to other expectations. The two environmental expectations with above-average weight were positive ones: recovering and valuing forest residues (getting rid of decaying residue piles is likely seen as an improvement of forest landscapes) and production of a renewable and less-polluting energy source. Mitigation of climate change (also positive) was, however, ranked lower than the average. La Tuque community members perceived the concern that the establishment of the forest biorefinery might degrade the quality of their (forest-dominated) territory for recreational and touristic use as more important than the concern that it might degrade biodiversity and ecosystem services. The territory is heavily used for hunting, hiking and motorised activities. The local economy of La Tuque, the vitality of which ranks highest among expectations, also heavily relies on exploitation of forest resources, which need to be sustained for the long-term well-being of the community. La Tuque stakeholders did not appear to perceive forest biomass procurement for the biorefinery as a threat or particular concern to the ecological health of forest ecosystems; however, they are concerned about forest ecosystem quality as their own living environment and playground. This suggests that concepts such as preservation of biodiversity might be too abstract for most of the stakeholders, whereas indicators that directly relate to their well-being might be easier to grasp. This points to the importance of adapting communication of global issues so that local communities can see how they relate to their own life, well-being and living environment.

The planned forest biorefinery in La Tuque is an example of where forest bioenergy will be integrated within existing forest management systems. Forest biomass procurement will occur on managed public forest areas that are already under forest certification; governance of sustainability should (at least partially) be ensured by these certification systems, in addition to existing governmental forest regulations for public forest lands. The most recent Sustainable Forest Development Act in Quebec (in force since 2013) relies on the concept of ecosystem-based forest management, which has the goal of reducing the differences between managed forests and the natural forest in order to create landscapes that contain all the diversity of the natural forest. The high level of naturalness that this type of management maintains also causes a large variability in the quality of wood supply, forcing the industrial network to adapt to such variability. As such, polyvalent fiber-takers such as bioenergy developers can play a key role for silviculture by recovering residues and trees with fiber characteristics considered undesirable by the sawmills and pulpmills (e.g. wood from defoliated or dead trees; uncommercial hardwood species).

In some instances, biomass procurement can serve as an important silvicultural practice either by:

I. reducing residue loads on clearcut areas and accelerating the establishment and growth of the regenerating stand; or

II. allowing the harvest of stands that have a high proportion of undesirable trees (and were previously left untouched), and thus unlocking/mobilizing their portion of timber-quality volume.

In those cases, bioenergy can both displace fossil fuel and cause the additional benefits of: 1) increased carbon sequestration on forest sites, or 2) increased displacement effects of the newly mobilised volumes of sawn timber products reaching the markets. When properly documented, those benefits need to be taken into account when calculating the GHG balance of forest bioenergy systems (Figure 5).

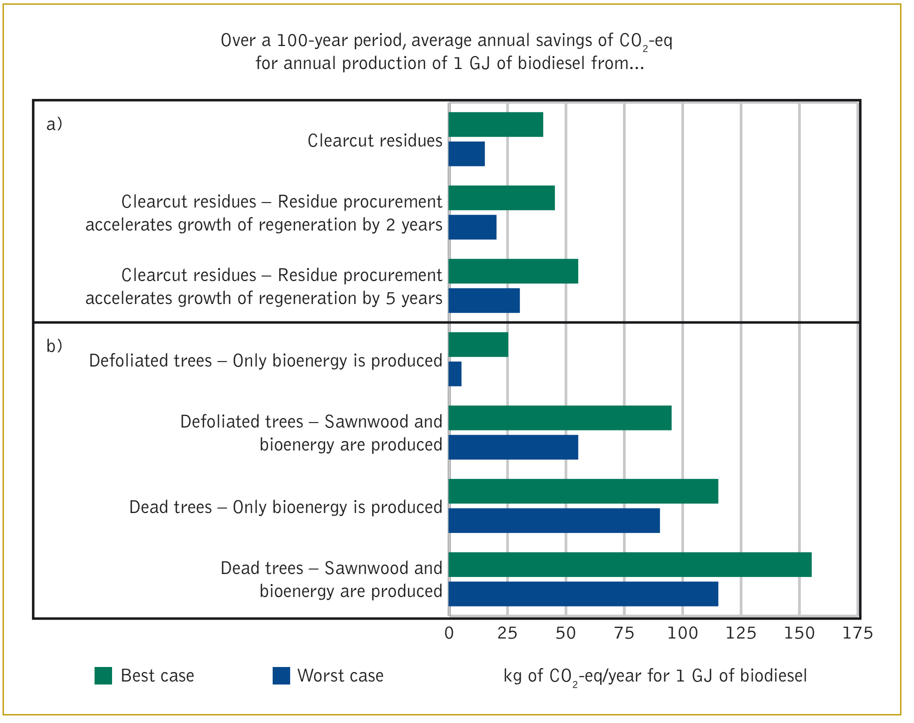

Figure 5: Example of calculation of CO_2-eq balance of forest bioenergy systems producing biodiesel from forest biomass from boreal balsam fir stands, relative to a reference system based on fossil diesel. Best/Worst case: Estimates of maximum/minimum savings based on variability of input parameters. Source: Thiffault et al. (2019).

Summary of main findings and conclusions

How to assess the sustainability of biomass and bioenergy supply chains?

Several of the included studies investigated how assessment approaches can influence results as well as conclusions of studies. The varying context of analyses and policy objectives influence the formulation of research questions, as well as the methodology design and parameter assumptions, e.g., which (fossil) fuels are substituted and what reference scenarios are chosen to compare with bioenergy scenarios. These in turn have a strong impact on the results and conclusions.

One example is forest bioenergy systems, where our work shows that the climate effects of forest based bioenergy systems need to be assessed in the **specific context** where bioenergy policies are developed and bioenergy is produced. For forest bioenergy, this often means that studies should analyse bioenergy systems as **components in value chains** or production processes that **also produce material products**, such as sawn wood, pulp, paper and chemicals.

Furthermore, assessments must consider how forest management, and the production and use of forest products, affect the strength of the forest carbon sink and the amount of carbon that is stored in forests and in forest products. Assessments should be made at the landscape level, to take full account of all the types of forest management operations that occur across the landscape. It is essential to include realistic representations of the age-dependence of forest growth rates so that it is considered that carbon accumulation rates diminish as forests age. Assessments that isolate bioenergy systems as single entities will not capture the full climate effect of implementing such systems. Results of such narrow studies are not sufficient bases for making conclusions about the climate effects of incentivising bioenergy and biobased products in general.

How to improve the input and output legitimacy of existing and proposed sustainability governance systems?

Work aimed at answering this question included building theory on how legitimacy of sustainability governance systems for bioenergy and the bioeconomy can be increased, as a basis for improving the granting and achieving of trust among relevant stakeholders, now and in the future. While we still consider it too early to suggest theories, we suggest new hypotheses, which we suggest will help to create trust in bioenergy. These were based on evidence found in several case studies:

- Include bioenergy policies and financial incentives as integrated parts of a comprehensive and holistic sustainability governance framework for bioenergy, which would define standards with a high level of democratic input, and tradeoffs involved based on data and scientific knowledge, where appropriate.
- Integrate governance with systems that transparently monitor the development of relevant indicators, and allow for open exchange of experiences among the involved actors.
- Develop sustainability governance systems to become more efficient, by using the available resources and time for targeted monitoring and auditing of issues with high sustainability risks.
- Make a long-term effort to engage with relevant actors for them to play the needed roles in mitigation of encountered sustainability risks.
- Build comprehensive spatial databases for documentation of sustainability against multiple standards, as this may render expensive management of unit level governance redundant over time.

We thus suggest that systems be created which take a **holistic and integrated approach** to sustainability standards, so that they include criteria e.g., for use of financial incentives and design of the renewable energy systems, together with the criteria that are already in the current standards. We also suggest initiating studies to **examine which mix** of mandatory and voluntary, and prescriptive and flexible governance measures are most **efficient and effective** in different conditions, and **how risk-based approaches** can help to obtain more cost-efficient and equally effective sustainability documentation.

It seems important to explore the opportunities that are offered by existing databases for documentation of sustainability, and how to further develop these and create new ones to address concerns as they emerge.

Finally, it seems important that **adaptive frameworks with monitoring and stakeholder communication platforms** are built into governance systems, to help regulators act with due diligence in matters of great complexity, as markets and governance systems go through different phases of development.

Even if these recommendations will not immediately close current significant 'trust gaps', we venture to hope that the suggested initiatives may help to clarify for all parties in the conversation how bioenergy and the bioeconomy can make a contribution to a more sustainable development in the near term, and in the more distant future.

How to engage more successfully with the broad range of stakeholders so that policies and sustainability governance are perceived as legitimate?

To begin with it is important to point out that public awareness of bioenergy in general is rather low, and information from academia and consulting is most trusted. For new (local) bioenergy projects, (better) informing and involving the public in advance could help identify concerns and expectations, and help develop more support for projects – or at least make risks transparent. Information about socio-economic benefits and participation/inclusion in bioenergy projects seems to be often neglected. Yet, these aspects are typically of high priority for many stakeholders. It also became clear that stakeholders outside of bioenergy supply chains concerned with social topics are typically less involved than those focusing on environmental aspects (such as respective NGOs). Engagement with and inclusion of civil society organisations (e.g., land owner and rural development organisations, labor unions) in the discourse, and communicating information on positive effects (without neglecting negative tradeoffs or risks) through their networks may help to balance the dialogue.

From the local projects investigated, the German biogas case met most resistance from many stakeholder groups in recent years. One approach suggested to reduce conflicts between the stakeholders is given by so-called best practice examples. Farmers have been able to reduce local conflicts without certification and standards by finding a compromise between local perception and an economic biogas plant operation. Sharing of economic benefits and fostering communication and good relationships have been shown to increase trust and understanding among stakeholders.

An analysis of supranational stakeholder views (Mai-Moulin et al. 2018) underlined that bioenergy market uncertainties and unresolved sustainability issues are identified as two main barriers to further bioenergy development. Social acceptance of bioenergy projects is also a real challenge to the bioenergy industry. Moreover, large-scale sustainable mobilisation of biomass feedstocks and governing increasing global trade are further challenges for the bioenergy sector to overcome in the medium- and long-term.

To receive **more support** from diverse stakeholder groups for the development of the bioenergy sector, the **establishment and implementation of sustainability safeguards** remains important. These include the **reduction of GHG emissions**, under stringent criteria with regard to **air and water pollution**; the **reuse and recycling of materials**; the improvement of **soil and forest management**; and the **conservation of biodiversity and ecosystem services**. Criteria on these issues have already been implemented in some EU Member States and could be further expanded to other countries.

In order to enhance and gain further support for the bioenergy sector, sustainability requirements covering social, and additional economic and environmental aspects may be considered for all types of biomass regardless of end use. It remains open whether mandatory implementation would ultimately lead to more stakeholder acceptance, and how realistic and rapid implementation for other end-uses is. Also, views of non-energy sectors (e.g. traditional wood product industries, biochemicals, biomaterials) are different, and partly consider competition with bioenergy for feedstocks as problematic, especially due to subsidies available for bioenergy.

From some of the work, it also became clear that there is a low support for energy crops on agricultural land from many stakeholder groups. This may well be linked to negative perceptions of indirect land use change (iLUC) caused by bioenergy incentives (and land use change, in general). This is problematic, as degraded agricultural land could be restored by energy crops (which constitute a significant share of the total global sustainable bioenergy potential, Fritsche et al. 2017).

If planting energy crops on marginal/degraded land (which is quite popular among NGO and policymakers) would be perceived as equivalent to planting energy crops on agriculture land (in general), this could (again) lead to incorrect perceptions about the sustainability of bioenergy. In addition, the perceived impacts of iLUC triggered by bioenergy, as well as possible ways to mitigate these potential impacts, need to be explained and communicated better.

Way forward and next steps

This Inter-Task project shows that science has come a long way in measuring and understanding important aspects relating to the sustainability of biomass and bioenergy supply chains. Yet, it is fair to say that – in parallel with results and solutions emerging – more questions have been raised and there is no uniform agreement among stakeholders on how sustainability of bioenergy systems should be measured and governed. Recommendations for further work include:

- The role and modes of communication in creating trust and confidence among actors, and the role of researchers in this process, need to be elaborated more: which role and modes are productive, and on which level (local/regional, national, international)?

- Based on experiences of the authors, supranational stakeholders should have more trust in local communities; if local communities already have trust in their own processes, practices, certification systems and professionals (as it appears to be the case in e.g. La Tuque), international/supranational stakeholders should take note of this.
- The extent to which sustainability standards and respective certification promote and incentivise continuous improvement should be investigated.
- Monitoring data at all levels is useful for documenting sustainability of bioenergy production and use and should be part of the assessment and communication with stakeholders
- There is no one single approach to assessing progress toward sustainability in any particular setting, but there are common threads. These general attributes include active stakeholder engagement throughout the process; transparent sharing of information about the social, economic, and environmental costs and benefits; ongoing monitoring; and working toward identifying and implementing better practices.

The recommendations and actions proposed above can only be realised as part of a long-term strategy, placed in the frame of the wider bioeconomy, and in collaboration with a variety of other institutions, individual countries and industries where the decision making power sits.

In November 2018, it was decided to focus follow-up work in a new IEA Bioenergy Task on "Climate and Sustainability Effects of Bioenergy within the Broader Bioeconomy" (Task 45). This Task will build further on the lessons learned from this project, and aims to deepen understanding of sustainability effects of bioenergy within the overall bioeconomy, to provide and improve respective tools, and to continue exploring suitable and agreeable governance approaches for a sustainable bioeconomy. For the latter, a transdisciplinary approach will be applied, aiming at opening up to and including stakeholders from the broader bioeconomy in the research process. We encourage all readers to refer to the Task 45 website (http://www.task45.ieabioenergy.com) for further information.

Acknowledgements

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