Energy, Sustainability and Society

EDITORIAL

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Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes

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Introduction

Agriculture and forestry produce a range of goods that are critical to human survival and welfare, including food and timber, and biomass feedstock for bioenergy, biochemicals, and biomaterials. The associated management activities span over large portions of the world's productive land and generate some of the largest human impacts on nature and the environment at scales that range from local to global. As the global population, its wealth, and interactions increase, the challenge to find an acceptable balance between human acquisition of food and raw materials and the impacts of such production on climate, nature, environment and people also increases.

Countries that increased their use of domestic biomass to substitute fossil fuels in modern bioenergy production after the oil embargo in the 1970s have also often adopted national recommendations for biomass harvesting in forests due to public concerns over the potential impacts of intensified management practices [1]. A booming international trade with bioenergy products since the 2000s [2] has led to creation of transnational sustainability regulation, often as a combination of national legal requirements and non-state certification to show compliance [3, 4]. The adopted and applied systems have been under public scrutiny from the beginning, but governance[1] is likely still one of the most useful tools available for finding agreement among stakeholders, or voters, on sustainability goals and criteria and indicators for measuring progress towards these goals [5].

The overall question addressed by this thematic article collection is how the choice of design of the sustainability governance system affects people's granting of legitimacy to the system. A high level of legitimacy is a precondition for building trust that the system leads to acceptable and beneficial outcomes. The question sits in the nexus

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[1] For the purpose of this article collection, we understand governance broadly as a range of public and private regulatory mechanisms. Public regulatory regimes include, for example, governmental regulation, ordinances, guidelines, BMPs, educational programmes, and public awareness campaigns, as well as international agreements and conventions with nations as signatories. Private regulatory regimes include non-state certification systems, standardisation, company policies such as Corporate Social Responsibility, organisations' or communities' BMPs and education programmes [1].

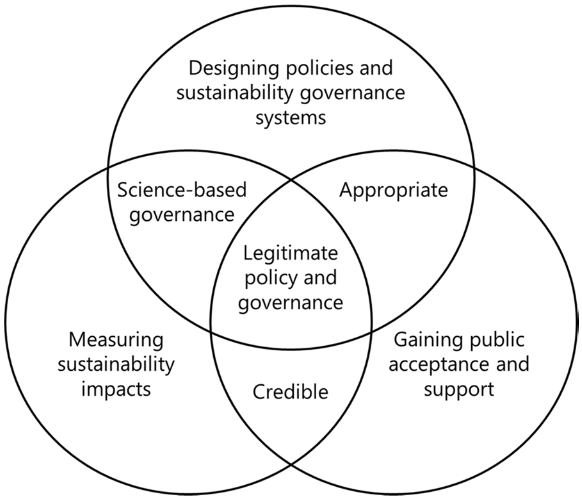

Fig. 1 A conceptual model for the nexus of science, policy and governance, and public acceptance in relation to sustainability governance for bioenergy and the bioeconomy

of science, policy and governance, and public acceptance [5–7] (Fig. 1). There is evidence that people are more likely to perceive a governance system as legitimate when rigorous science underpins its design, when the science is seen as credible, and when the system's exertion of power is seen to be fair and appropriate [5].

The model provided in Fig. 1 depicts the conceptual framework that underlies this article collection on sustainability governance of bioenergy and the bioeconomy. The included papers are part of a larger body of literature and knowledge generated from collaborative activities in research networks and projects funded by International Energy Agency (IEA) Bioenergy and the Nordic Council of Ministers, with contributions from the participating researchers' home organisations. The outputs include scientific articles, reports, workshops, and excursions that all have sought to increase the level of integration between science, policy and governance in relation to sustainability governance for bioenergy.

International collaboration

The IEA Bioenergy research collaboration on forest resource mobilisation through intensive logging residue and whole-tree harvesting started in the early 1970s, with associated investigations of how it affects site fertility and other ecological values. Several countries needed such knowledge when interest in the use of domestic forest biomass for energy increased after the oil embargo in 1973 [1, 5]. The collaboration on the topic continued in a dynamic research and knowledge exchange environment created by workshops and projects under various IEA Bioenergy Tasks with national research in participating member states as a basis. As the body of scientific literature grew, books, articles and reports synthesised knowledge to inform forest management and policy. Major works include the books Dyck et al. (1994) "Impacts of Forest Harvesting on Long-Term Site Productivity" [8] and Richardson et al. (2002) "Bioenergy from Sustainable Forestry—Guiding Principles and Practice" [9]. A European Union R&D project also produced a book within the same topic area: Röser et al. (2008) "Sustainable Use of Forest Biomass for Energy—A Synthesis with Focus on the Baltic and Nordic Region" [10]. Articles developed from these collaborations during the period 2007–2013 also proposed and reviewed criteria and indicators for sustainable wood fuel production from forests [11–15], and the IEA Bioenergy strategic study "Monitoring Sustainability Certification of Bioenergy" (2012–2013) examined the potential role of voluntary certification schemes in the governance of bioenergy sustainability, how these schemes affect supply chain actors [16], and perceptions if existing systems are adequate [17].

The boom in the transatlantic wood pellet trade in the early 2010s, especially from North America to Europe [2], created a sense of urgency to improve communication through dialogues around the scientific basis for regulation and governance of the sustainability of forest bioenergy. Workshops in Quebec, Canada, 2012 [18] and in Arona, Italy, 2013 [19] discussed, for example, the application of the term "primary forest" in sustainability requirements of the European Union Renewable Energy Directive from 2009 [20] (Fig. 2). It had become a significant concern that such terminology does not easily translate into a North American context.

The increasing volumes of internationally traded wood pellets also gave rise to new concerns about whether forest bioenergy is truly leading to climate benefits. This motivated another workshop in Savannah, Georgia, USA, in 2013 [21], which provided a platform for discussions on methodology and assumptions for calculation of greenhouse gas emission savings from forest bioenergy. This debate is still energetically ongoing today [5] and continues to give rise to new studies on greenhouse gas emission savings, also in this article collection.

The international trade with bioenergy products further stimulated interest in broader bioenergy sustainability criteria, potentially covering a range of supply chains and feedstocks. A tour across the landscapes of southeastern North America in 2016 to discuss a range of bioenergy production systems [22] provided inspiration for the newly started IEA Bioenergy project "Measuring, governing and gaining support for sustainable bioenergy supply chains" [23]. The project had three objectives

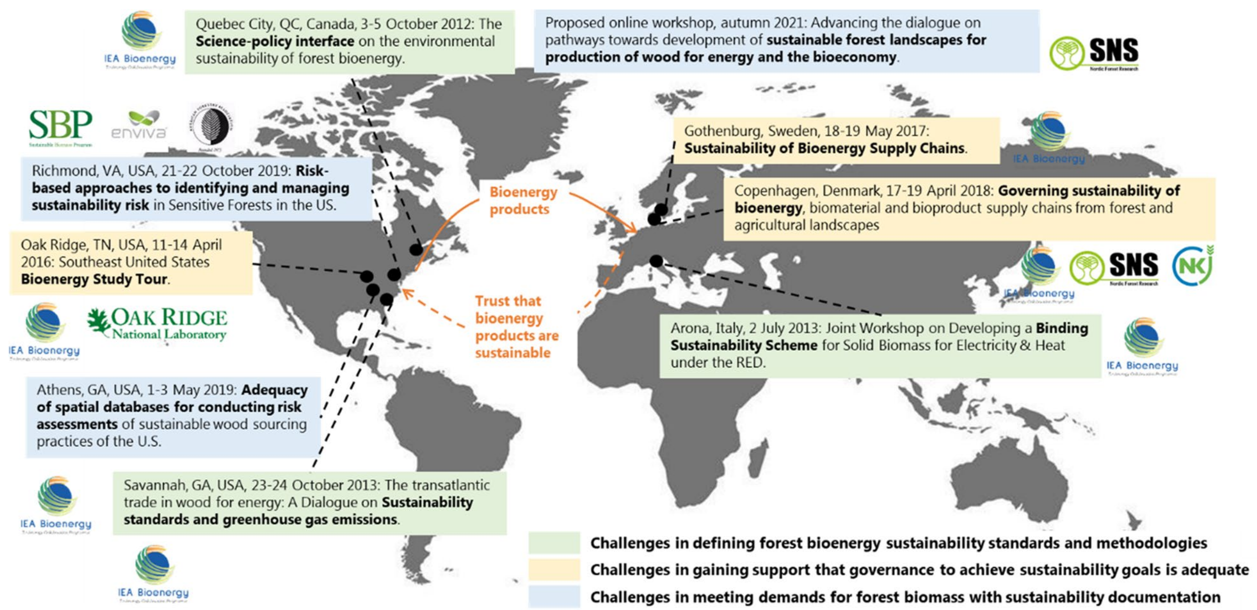

Fig. 2 Workshops, conferences and tours that are part of what we refer to as the transatlantic dialogue on sustainability of bioenergy

under which it commissioned a number of studies relating to measuring, governing, and gaining support for sustainable bioenergy supply chains, respectively, corresponding to the three components of the model in Fig. 1. Preliminary results were presented during a workshop in Gothenburg, Sweden, in 2017 [24].

In 2018, IEA Bioenergy Task participants joined forces with the Nordic–Baltic networks "Effect of bioenergy production from forests and agriculture on ecosystem services in the Nordic and Baltic landscapes" and "Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems", funded by Nordic Forest Research and The Nordic Joint Committee for Agricultural and Food Research, to arrange a conference in Copenhagen, Denmark, titled "Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes" [25]. The conference focussed on questions around design of effective and legitimate science-based sustainability governance for bioenergy and the bioeconomy, with the ultimate criterion for a "good" design being high levels of public trust that bioenergy production only takes place when and where it is sustainable. Long-term and new collaborators presented analyses of governance systems, impacts, and stakeholder perceptions in relation to bioenergy supply chains based on forest or agriculture biomass, or manure for biogas, as during the IEA Bioenergy inter-Task project. Some main conclusions were synthesised and presented to larger audiences the same year at the European Biomass and Exhibition (EUBCE) in Copenhagen, Denmark [26], and at the IEA Bioenergy Triennial Summit in San Francisco, California, USA [27].

It became clear that it is not possible to satisfy the demand for certified biomass only with systems based on management unit-level certification [4]. This increased the interest in sourcing area and regional risk-based approaches to document compliance with sustainability criteria. A workshop in Athens, Georgia, USA, focused on advanced spatial data and their usefulness for conducting risk assessments for sustainable wood sourcing practices in the USA [28], and a workshop in Richmond, Virginia, USA, discussed the application of risk-based approaches especially in sensitive forests in the USA [29].

This article collection mainly contains a sub-set of articles produced under the inter-Task project and/or presented at the conference in Copenhagen in 2018 (see Table 1). However, other publications produced in the same context have also been included for the overview provided in the next section (see Table 2).

Table 1 Studies included in this article collection in Energy, Sustainability and Society

A1	Hansen AC, Clarke N, Hegnes AW (2021) Managing sustainability risks of bioenergy in four Nordic countries. Energy Sustain Soc (accepted for publication)
A2	Titus BD, Brown KR, Helmisaari H–S, Vanguelova E, Stupak I, Evans A, Clarke N, Guidi C, Bruckman VJ, Varnagiryte-Kabasinskiene I, Armolaitis K, de Vries W, Hirai K, Kaarakka L, Hogg K, Reece P (2021). Sustainable forest biomass: a review of current residue harvesting guidelines. Energy Sustain Soc 11:10. https://doi.org/10.1186/s13705-021-00281-w
A3	Stupak I, Mansoor M, Smith CT (2021) Conceptual framework for increasing legitimacy and trust of sustainability governance. Energy Sustain Soc 11:5. https://doi.org/10.1186/s13705-021-00280-x
A4	Kittler B, Stupak I, Smith CT (2020) Assessing the wood sourcing practices of the U.S. industrial wood pellet industry supplying European energy demand. Energy Sustain Soc 10:23 https://doi.org/10.1186/s13705-020-00255-4
A5	Moosmann D, Majer S, Ugarte S, Ladu S, Wurster S, Thrän D (2020) Strengths and gaps of the EU frameworks for the sustainability assessment of bio-based products and bioenergy. Energy Sustain Soc 10:22. https://doi.org/10.1186/s13705-020-00251-8
A6	Tilvikiene V, Venslauskas D, Povilaitis V, Navickas K, Zuperka V, Kadziuliene Z (2020). The effect of digestate and mineral fertilisation of cocksfoot grass on greenhouse gas emissions in a cocksfoot-based biogas production system. Energy Sustain Soc 10:13. https://doi.org/10.1186/s13705-020-00245-6
A7	Thrän D, Schaubach K, Majer S, Horschig T (2020). Governance of sustainability in the German biogas sector—adaptive management of the Renewable Energy Act between agriculture and the energy sector. Energy Sustain Soc 10:3 https://doi.org/10.1186/s13705-019-0227-y
A8	Mai-Moulin T, Fritsche UR, Junginger M (2019) Charting global position and vision of stakeholders towards sustainable bioenergy. Energy Sustain Soc 9:48 https://doi.org/10.1186/s13705-019-0225-0
A9	Gan J, Stupak I, Smith CT (2019) Integrating policy, market, and technology for sustainability governance of agriculture-based biofuel and bio-economic development in the US. Energy Sustain Soc 19) 9:43. https://doi.org/10.1186/s13705-019-0223-2
A10	Varnagirytė-Kabašinskienė I, Lukminė D, Mizaras S, Beniušienė L, Armolaitis K (2019) Lithuanian forest biomass resources: legal, economic and ecological aspects of their use and potential. Energy Sustain Soc 9:41. https://doi.org/10.1186/s13705-019-0229-9
A11	Bentsen NS, Larsen S, Stupak I (2019) Sustainability governance of the Danish bioeconomy — the case of bioenergy and biomaterials from agriculture. Energy Sustain Soc 9:40. https://doi.org/10.1186/s13705-019-0222-3
A12	Pestalozzi J, Bieling C, Scheer D, Kropp C (2019) Integrating power-to-gas in the biogas value chain: analysis of stakeholder perception and risk governance requirements. Energy Sustain Soc 9:38. https://doi.org/10.1186/s13705-019-0220-5
A13	Larsen S, Bentsen NS, Stupak I (2019) Implementation of voluntary verification of sustainability for solid biomass—a case study from Denmark. Energy Sustain Soc 9:33 https://doi.org/10.1186/s13705-019-0209-0
A14	Stanturf JA, Perdue JH, Young TM, Huang X, Guo Z, Dougherty D, Pigott M (2019) A spatially explicit approach to modeling biological productivity and economic attractiveness of short-rotation woody crops in the eastern USA. Energy Sustain Soc 9:28. https://doi.org/10.1186/s13705-019-0211-6

Overview of articles and future perspectives

Studies conducted within the context of the above collaborations generally focussed on one of the three research areas (Table 3), corresponding to the components of the model in Fig. 1: “Governance system design”, “the underpinning science”, and “stakeholder perceptions and engagement”, combined with one of three generalised types of bioenergy supply chains. The generalised supply chains were defined by their dominant type of feedstock and typical energy end-use, where feedstock types included forest biomass, agricultural crop residues and perennial crops, and animal manure for biogas (Table 3). Other studies more broadly addressed conceptual understandings, all bioenergy sectors together, or the bioeconomy as a whole, but most studies could be categorised as addressing one of the three research focuses for one of the three types of supply chains (Table 3).

The studies provide an opportunity to deduce and compare lessons learned from each of the three types of supply chains, across a range of domestic and international supply chains that involve different geographical regions for both feedstock production and bioenergy end-use (Table 3). Positive experiences from one supply chain may be applicable for the two other supply chain types. A detailed analysis and synthesis is beyond the scope of this editorial, but Stupak et al. [5] present a research

Table 2 Articles and reports closely connected with this article collection but published elsewhere

B1	Al Seadi T, Stupak I, Smith CT (2018) Governance of environmental sustainability of manure-based centralised biogas production in Denmark. Murphy JD (Ed.) IEA Bioenergy Task 37, 2018: 7, 31 pp. https://www.ieabioenergy.com/blog/publications/governance-of-environmental-sustainability-of-manure-based-centralised-biogas-production-in-denmark/
B2	Bentsen NS, Jørgensen JR, Stupak I, Jørgensen U, Taghizadeh-Toosid A (2019) Dynamic sustainability assessment of heat and electricity production based on agricultural crop residues in Denmark. J Clean Prod 213:491–507. https://doi.org/10.1016/j.jclepro.2018.12.194
B3	Cheung Q, Smith CT, Stupak I (2019). Governance of sustainable forest management and bioenergy feedstock harvesting in Ontario, Canada. IEA Bioenergy: Task 43: Technical Report, TR2019:04, 62 pp. https://task43.ieabioenergy.com/publications/governance-of-sustainable-forest-management-and-bioenergy-feedstock-harvesting-in-ontario-canada/
B4	Dale VH, Kline KL, Richard TL, Karlen DL, Belden WW (2018). Bridging biofuel sustainability indicators and ecosystem services through stakeholder engagement. In a Special Issue on "Biofuels and Ecosystem Services". Biomass Bioenerg 114:143–156. https://doi.org/10.1016/j.biombioe.2017.09.016
B5	Diaz-Chavez R, van Dam J (2020) Novel regional and landscape based approaches to govern sustainability of bioenergy and biomaterials supply chains. IEA Bioenergy: Task 43: TR2020-02, 153 pp. https://www.ieabioenergy.com/blog/publications/new-publication-novel-regional-and-landscape-based-approaches-to-govern-sustainability-of-bioenergy-and-biomaterials-supply-chains/
B6	Kline KL, Parish ES, Dale VH (2018) The importance of reference conditions in assessing effects of bioenergy wood pellets produced in the south-eastern United States. World Biomass 2018–2019; p 82–86. DCM Productions, United Kingdom. http://dcm-productions.co.uk/world-biomass-2018-2019/
B7	Lalonde C, Wellisch M (2020) Sustainability governance of Canada's agriculture-based bioeconomy. IEA Bioenergy: Task 43, September 2020, 96 pp. https://www.ieabioenergy.com/blog/publications/new-publication-sustainability-governance-of-canadas-agriculture-based-bioeconomy/
B8	Nair S, Griffel LM, Hartley D, Mcnunn G, Kunz MR (2018) Investigating the Efficacy of Integrating Energy Crops into Non-Profitable Subfields in Iowa. BioEnergy Res 11(10):1–15. https://doi.org/10.1007/s12155-018-9925-0
B9	Stupak I, Smith CT (2018) Feasibility of verifying sustainable forest management principles for secondary feedstock to produce wood pellets for co-generation of electricity in the Netherlands. IEA Bioenergy Task 43 TR2018-01, 54 pp. https://www.ieabioenergy.com/blog/publications/feasibility-of-verifying-sustainable-forest-management-principles-for-secondary-feedstock-to-produce-wood-pellets-for-co-generation-of-electricity-in-the-netherlands/

framework for conducting such an analysis, and a model for adaptive governance that builds on the collective sum of experiences and understanding gained from the individual studies (Table 3), the broader research network collaborations, and other literature on the topic.

The model suggests that a well-designed adaptive approach to governance will positively affect the quality of the stakeholder participation ("input legitimacy") as well as the ability of the system to achieve environmental, social, economic or cultural sustainability goals and avoid undesired impacts ("output legitimacy"). Both issues have been shown to be critical for gaining support for governance (Fig. 3). An additional critical element is the efficiency in implementation and enforcement, as well as the efficient, fair, truthful, and transparent conduct of system affairs generally ("throughput legitimacy").

The adaptive governance cycle comprises steps to identify sustainability concerns, design policy and standards to address them, and design implementation and enforcement systems, as well as monitoring-and-evaluation systems. Finally, lessons learned and recommendations are deduced for system revision, and the cycle starts again with identification of new concerns or dissatisfactions, needs to correct unintended impacts, and adaptations to new technologies or framework conditions. The monitoring-and-evaluation system is thus a critical element of the adaptive cycle, as it tracks progress towards the intended goals and facilitates the development and improvement of the quality of the governance system processes.

While governance is a beneficial tool for resolving disagreement, we assert that value-based political and public discourses will continue to influence political decisions and public opinion, and these may at times overrule the

Table 3 Overview of papers of this article collection (see Table 1) as well as those written within the same context but published elsewhere (see Table 2), categorised according to the addressed type of supply chain and type of research focus

Supply chains component	Type of supply chain		
	Forest	**Agriculture**	**Biogas**
Feedstock	Primary, secondary and tertiary woody biomass	Crop residues, perennial energy crops	Manure, energy crops, agricultural residues
End-use	Heat and power	Transportation fuels, heat and power	Heat and power, transportation
Type of research focus	**Type of supply chain**		
	Forest	**Agriculture**	**Biogas**
Conceptual basis, theory	*General* A3. Stupak et al. (2021). Conceptual framework		
Governance system design	*North America* A4. Kittler et al. (2020). Southeastern USA B3. Cheung et al. (2019). Ontario, Canada *North America and Europe* A2. Titus et al. (2021). Northern hemisphere B9. Stupak and Smith (2018). SE USA and Baltic states *Europe* A13. Larsen et al. (2019). Denmark A1. Hansen et al. (2021). Fennoscandia	*North America* A9. Gan et al. (2019). The USA B7. Lalonde and Wellisch (2020). Canada *Europe* A11. Bentsen et al. (2019). Denmark and the EU	*Europe* A7. Thrän et al. (2020). Germany B1. Al Seadi et al. (2018). Denmark
	General A5. Moosmann et al. (2020). The EU B5. Diaz-Chavez and van Dam (2020). African, Asian and South American countries		
The underpinning science	*North America* B6. Kline et al. (2018). SE USA. Greenhouse gas emissions *Europe* A1. Hansen et al. (2021). Fennoscandia. Sustainability A10. Varnagirytė-Kabašinskienė et al. (2019). Lithuania. Environmental issues	*North America* B8. Nair et al. (2018). Iowa, USA. Productivity A14. Stanturf et al. (2019). Eastern USA. Economics *Europe* B2. Bentsen et al. (2018). Denmark. GBEP sustainability indicators	*Europe* A6. Tilvikiene et al. (2020). Lithuania. Greenhouse gas emissions
Perceptions and stakeholder engagement		*North America* B4. Dale et al. (2018). Iowa, USA	*Europe* A12. Pestalozzi et al. (2019). Germany
	General A8. Mai-Moulin et al. (2019). Global		

The topic is indicated for papers listed under "The underpinning science"

outcomes of monitoring and research. This is an important condition in democratically governed societies. To this end, it is also important to recognise that research does not take place in an entirely value-free, objective, and neutral space. This means that transparency around funding, topic selection, chosen methodology, etc., becomes crucial to avoid suspicion about scientific results, especially when there are value-based disagreements. We venture to hope that the articles in this collection fulfil the transparency criterion, especially, but also that the presented work may inform and inspire the development of sustainability governance systems in the future.

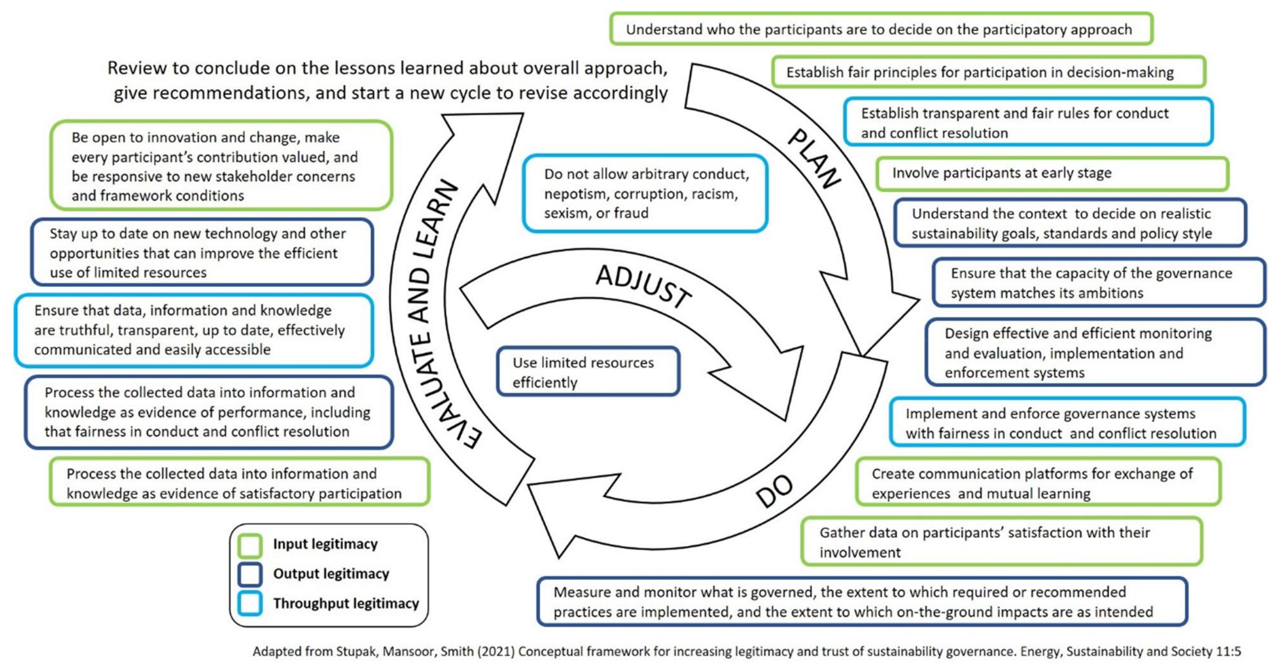

Fig. 3 Model for adaptive sustainability governance with proposed linkages with the principles and open-ended criteria for "good" sustainability governance, organised under three legitimacy principles: input, output, and throughput legitimacy

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Authors' contributions
All authors jointly conceived the ideas behind the editorial. IS compiled it with continued feedback and suggestions from CTS and NC. All authors read and approved the final manuscript.

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Declarations

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Consent for publication
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Competing interests
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References
1. Titus BD, Brown KR, Helmisaari H-S, Vanguelova E, Stupak I, Evans A, Clarke N, Guidi C, Bruckman VJ, Varnagiryte-Kabasinskiene I, Armolaitis K, de Vries W, Hirai K, Kaarakka L, Hogg K, Reece P (2021) Sustainable forest biomass: a review of current residue harvesting guidelines. Energy Sustain Soc 11:10. https://doi.org/10.1186/s13705-021-00281-w
2. Thrän D, Schaubach K, Peetz D, Junginger M, Mai-Moulin T, Schipfer F, Olsson O, Lamers P (2018) The dynamics of the global wood pellet markets and trade – key regions, developments and impact factors. Biofuels Bioprod Biorefining 13(1):267–280. https://doi.org/10.1002/bbb.1910

3. Larsen S, Bentsen NS, Stupak I (2019) Implementation of voluntary verification of sustainability for solid biomass—a case study from Denmark. Energy Sustain Soc 9:33. https://doi.org/10.1186/s13705-019-0209-0
4. Stupak I, Smith CT (2018) Feasibility of verifying sustainable forest management principles for secondary feedstock to produce wood pellets for co-generation of electricity in the Netherlands. IEA Bioenergy Task 43 TR2018-01. https://www.ieabioenergy.com/blog/publications/feasibility-of-verifying-sustainable-forest-management-principles-for-secondary-feedstock-to-produce-wood-pellets-for-co-generation-of-electricity-in-the-netherlands/
5. Stupak I, Mansoor M, Smith CT (2021) Conceptual framework for increasing legitimacy and trust of sustainability governance. Energy Sustain Soc 11:5. https://doi.org/10.1186/s13705-021-00280-x
6. Richardson J (2011) Sustainable forestry systems for bioenergy: Integration, innovation and information. Biomass Bioenerg 35(8):3285–3286. https://doi.org/10.1016/j.biombioe.2011.06.040
7. Magar SB, Pelkonen P, Tahvanainen L, Toivonen R, Toppinen A (2011) Growing trade of bioenergy in the EU: Public acceptability, policy harmonization, European standards and certification needs. Biomass Bioenerg 35(8):3318–3327. https://doi.org/10.1016/j.biombioe.2010.10.012
8. Dyck WJ, Cole DW, Comerford NB (1994) Impacts of forest harvesting on long-term site productivity. Chapman and Hall, London
9. Richardson J, Björheden R, Hakkila P, Lowe AT, Smith CT (2002) Bioenergy from sustainable forestry—guiding principles and practice. Kluwer Academic Publishers, Dordrecht
10. Röser D, Asikainen A, Raulund-Rasmussen K, Stupak I (eds) (2008) Sustainable use of forest biomass for energy. A synthesis with focus on the Baltic and Nordic region. Springer, New York
11. Stupak I, Asikainen A, Jonsell M, Karltun E, Lunnan A, Mizaraite D, Pasanen K, Pärn H, Raulund-Rasmussen K, Röser D, Schroeder M, Varnagiryte I, Vilkriste L, Callesen I, Clarke N, Gaitnieks T, Ingerslev M, Mandre M, Ozolincius R, Saarsalmi A, Armolaitis K, Helmisaari H-S, Indriksons A, Kairiukstis L, Katzensteiner K, Kukkola M, Ots K, Ravn H-P, Tamminen P (2007) Sustainable utilisation of forest biomass for energy—possibilities and problems: policy, legislation, certification, and recommendations and guidelines in the Nordic, Baltic, and other European countries. Biomass Bioenerg 31(10):666–684. https://doi.org/10.1016/j.biombioe.2007.06.012
12. Lattimore B, Smith CT, Titus BD, Stupak I, Egnell G (2009) Environmental factors in woodfuel production: opportunities, risks, and criteria and indicators for sustainable practices. Biomass Bioenerg 33(10):1321–1342. https://doi.org/10.1016/j.biombioe.2009.06.005
13. Lattimore B, Smith T, Richardson J (2010) Coping with complexity: designing low-impact forest bioenergy systems using an adaptive forest management framework and other sustainable forest management tools. For Chron 86(1):20–27. https://doi.org/10.5558/tfc86020-1
14. FAO (2010) Criteria and indicators for sustainable woodfuels. Food and Agriculture Organization of the United Nations (FAO). FAO Forestry Paper 160. http://www.fao.org/docrep/012/i1673e/i1673e00.htm
15. Stupak I, Lattimore B, Titus BD, Smith CT (2011) Criteria and indicators for sustainable forest fuel production and harvesting: a review of current standards for sustainable forest management. Biomass Bioenerg 35(8):3287–3308. https://doi.org/10.1016/j.biombioe.2010.11.032
16. Pelkmans L, Goovaerts L, Stupak I, Smith CT, Goh CS, Junginger M, Chum H, Eng AG, Cowie A, Englund O, Joudrey J, Dahlman L (2013) Monitoring sustainability certification of bioenergy – short summary. Strategic Inter-Task study, commissioned by IEA Bioenergy Carried out in cooperation between IEA Bioenergy Task 40, Task 43 and Task 38, June 2013. IEA Bioenergy: ExCo:2013:05. https://www.ieabioenergy.com/blog/publications/monitoring-sustainability-certification-of-bioenergy-short-summary/
17. Stupak I, Joudry J, Smith CT, Pelkmans L, Chum H, Cowie A, Englund O, Goh CS, Junginger M (2016) A global survey of stakeholder views and experiences for systems needed to effectively and efficiently govern sustainability of bioenergy. WIREs Energy Environ 5:89–118. https://doi.org/10.1002/wene.166
18. IEA Bioenergy (2013) The Science-Policy Interface on the Environmental Sustainability of Forest Bioenergy. A Strategic Discussion Paper. IEA Bioenergy: ExCo:2013:03, 12 pp. Outcome paper from the workshop held in Quebec City, Quebec, Canada, 3–5 October 2012. https://www.ieabioenergy.com/blog/publications/the-science-policy-interface-on-the-environmental-sustainability-of-forest-bioenergy/
19. Fritsche UR, Iriarte L, de Jong J, van Thuijl E, Lammers E, Agostini A, Scarlat N, Hennenberg K, Wiegmann K, Czopek P (2012) Outcome Paper: Sustainability Criteria and Indicators for Solid Bioenergy from Forests based on the Joint Workshops on Extending the RED Sustainability Requirements to Solid Bioenergy. December 2012, revised June 2013. Discussed in the "Joint Workshop on Developing a Binding Sustainability Scheme for Solid Biomass for Electricity & Heat under the RED" held in Arona, Italy, 2 July 2013. http://www.iinas.org/tl_files/iinas/downloads/Joint_WS_Outcome_Paper_2012.pdf
20. EU (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Off J Eur Union, L 140/16. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028
21. Pinchot Institute (2013) The Transatlantic Trade in Wood for Energy. A Dialogue on Sustainability Standards and Greenhouse Gas Emissions. Pinchot Institute, 20 pp. Outcome paper from workshop held in Savannah, Georgia, USA, 23–24 October 2013, 20 pp. https://www.ieabioenergy.com/blog/publications/savannah-sustainability-workshop/
22. "Southeast United States Bioenergy Study Tour". Field excursions, Oak Ridge, Tennessee, USA, 11–14 April 2016: https://www.ornl.gov/news/ornl-hosts-southeast-bioenergy-meeting-study-tour
23. "Measuring, governing and gaining support for sustainable bioenergy supply chains". IEA Bioenergy inter-Task project 2016–2018. https://www.ieabioenergy.com/blog/publications/new-publication-measuring-governing-and-gaining-support-for-sustainable-bioenergy-supply-chains/
24. "Sustainability of bioenergy supply chains. Summary from an inter-Task workshop 18–19 May 2017, Gothenburg, Sweden" (2017) IEA Bioenergy workshop held in Gothenburg, Sweden, 18–19 May 2017. IEA Bioenergy: Inter-Tasks Sustainability of Bioenergy Supply Chains ExCo: 2017: 08, 45 pp. https://www.ieabioenergy.com/blog/publications/sustainability-of-bioenergy-supply-chains-workshop-summary/
25. "Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes". Conference held in Copenhagen, Denmark, 17–19 April 2018. https://ign.ku.dk/english/bioenergy-dialogues/
26. "Sustainability governance of bioenergy supply chains". Session in the "European Biomass Conference & Exhibition (EUBCE), held in Copenhagen, Denmark, 15 May 2018. https://itp-sustainable.ieabioenergy.com/events/
27. "Sustainability Forum" of the IEA Bioenergy Triennial Summit, held back to back with the "Advanced Bioeconomy Leadership Conference" (ABLC) in San Francisco, California, USA, 7 November 2018. https://www.ieabioenergy.com/blog/publications/iea-bioenergy-conference-2018/
28. "Adequacy of spatial databases for conducting risk assessments of sustainable wood sourcing practices of the U.S." Workshop held in Athens, Georgia, USA, 1–3 May 2019. https://task43.ieabioenergy.com/publications/international-workshop-adequacy-of-spatial-databases-for-conducting-risk-assessments-of-sustainable-wood-sourcing-practices-of-the-u-s-industrial-wood-pellet-industry-supplying-european-energy-dema/
29. "Risk-Based Approaches to Identifying and Managing Sustainability Risk in Sensitive Forests in the US". Workshop held in Richmond, Virginia, USA, 21–22 October 2019.

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