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OPINION

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A value chain approach to improve biomass policy formation

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Abstract

Biomass value chains for energy, fuels and bio-based products involve complex, cross sector interactions between their upstream and downstream stages. Overarching policymaking to date has included the use of biomass to deliver sector specific aims (e.g. climate change, energy, etc.) however, this is mostly planned without adjusting support across the most challenging stages of biomass value chains and exploiting specific advantages related to their geographic settings (e.g. domestic feedstocks, local markets, etc.). Policies to date have, therefore, resulted in fragmented, suboptimal biomass use and debates for sustainability and resource efficiency. This opinion paper arose from the project Strategic Initiative for Resource Efficient Biomass Policies Funded by the EU Commission. It discusses the development of a dedicated Biomass Policy Framework which applies the principles of value chain analysis in policy design to enable the market uptake of sustainable, domestic, resource efficient biomass solutions. Firstly, it explains how to provide context by identifying value chains which can offer competitive advantages for biomass mobilization, market infrastructures, rural and economic development within their geographic setting. Then the work builds on the context and prioritized value chains and further rationalizes policy needs and aims within individual value chain stages. This is done by identifying policy-related challenges and gaps that constrain sustainable and resource efficient deployment of the selected value chains. Also, it suggests policy interventions that will overcome challenges, resolve gaps and as a result mobilize local biomass and improve market uptake. Finally, it discusses the contrasting paradigms for biomass policy formation within single sector target setting and the value chain approach of the Biomass Policy Framework and uses the case of low carbon biomass heat to illustrate the strengths of the suggested approach. The paper concludes with remarks for the concept of biomass value chain analysis in policy.

KEYWORDS

bio-based products, bioenergy, biomass, policy, value chain analysis

1 | INTRODUCTION

A biomass value chain comprises sequential, interdependent economic activities including land use and feedstock production, conversion to energy or bio-based carriers, and finally variable markets using the end products. They involve complex, cross-sectoral interactions between their upstream and downstream stages. Moreover, their suitability, efficiency and appropriate implementation scales depend on geographical and climate features, so their optimal performance tends to be region- and case specific.

Biomass policy formation to date is mostly driven by fragmented contributions to overarching sector imperatives, with climate change and the energy industry (European Commission, 2018; European Union, 2009) typically being the leading ones, and does not successfully capture the complete merits of biomass value chains (Panoutsou et al., 2013; Ruamsook & Thomchick, 2014) within their regional or national context. This process has resulted in suboptimal interventions, inhibiting market uptake of options that are domestically sourced, resource efficient and well integrated with the specificities of each region.

This paper discusses an empirically evidenced value chain approach, the Biomass Policy Framework, designed to foster dedicated biomass policymaking by tailoring interventions across the different stages of value chains, exploiting advantages within specific geographic settings and consequently achieving higher market uptake.

The Biomass Policy Framework is a combination of analytical, modelling and participatory processes that require extensive engagement of stakeholders involved across all value chain stages. They must be consulted to consider challenges and gaps across the biomass value chain—including feedstock availability, resource efficiency and sustainability—and policy options to develop and sustain market uptake (Schmitz, 2005). Their engagement facilitates communication of specific actions and planned interventions and actively involves them in participatory decision-making process (Bellù, 2013). A broad-based stakeholder participatory process is widely recommended by similar research work since it can create added value (De Marchi, 2003; Janssen & Helbig, 2018; Maher & Buhmann, 2019), give better results and facilitate wider public acceptance (Fritz, Rauter, Baumgartner, & Dentchev, 2018; Wiesmeth, 2018). The framework is flexible and can be applied to any geographical scale—local, regional or national. This approach has been tested successfully in the framework of the Biomass Policies project during a period of 3 years (2013–2016). The Biomass Policy Framework has been applied to 53 value chains, across 11 European countries (AT, BE, DE, ES, FI, GR, HR, NL, PL, SK, UK) through 20 national events with the participation of 750 stakeholders representing different parts of the value chain.

The value chain approach presented in this opinion paper fits well into similar models from literature which define agenda, decision and implementation as the main policy formation stages. Figure 1 shows how the Biomass Policy Framework matches the three stages. This type of policy model is normally described as 'rational' or 'linear' (Slade, Panoutsou, & Bauen, 2009; Sutton, 1999). Policymaking is viewed as problem-solving process, which is linear or rational, balanced, objective and analytical. Decisions are made in sequential phases, start with 'identification of a problem' and end with 'set of activities to solve or deal with it'. It can complement overarching sector targets and facilitate reaching them in a more resource efficient and sustainable manner through mobilizing domestic biomass streams and at the same time meeting the needs of local communities and facilitating rural and economic development.

The paper is structured in six sections. The first section outlines the Biomass Policy Framework stages. The second section describes how to contextualize opportunities within a given geographic setting with respect to domestically sourced biomass value chains, markets and policy. The third section builds on the prioritized value chains and context, and further rationalizes policy needs by identifying policy-related challenges and gaps that need to be addressed and defining relevant policy aims. The fourth section identifies potential policy interventions that can alleviate challenges and resolve gaps. The fifth section debates why the Biomass Policy Framework approach can better stimulate resource efficient

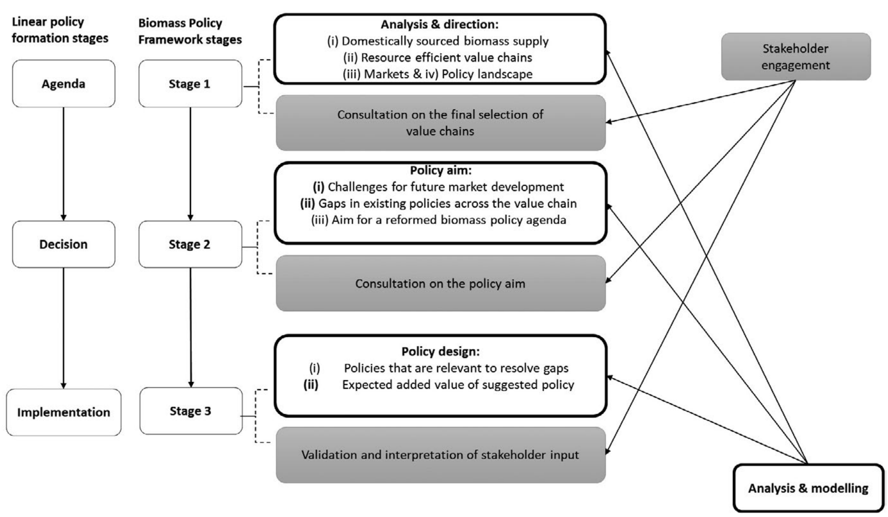

FIGURE 1 Steps included in the Biomass Policy Framework

uptake of biomass and uses the case of low carbon biomass heat to illustrate the strengths of the suggested approach. Finally, the sixth section provides concluding remarks for the concept of Biomass Policy Framework in policy formation.

2 | THE BIOMASS POLICY FRAMEWORK

The Biomass Policy Framework presented here can help deliver a dedicated biomass policy by analysing and understanding how interventions that are integrated across the biomass value chain stages can overcome individual challenges and resolve gaps in a more effective way than isolated sector-specific policies. Such policy formation would allow policymakers to recognize the value chain stages that need further support and develop targeted interventions that can increase market uptake of domestic feedstocks within geographical settings. These policies can better capitalize on the strengths and opportunities, prioritize the resource efficient mobilization of domestic biomass value chains and address the prevailing challenges and policy relevant gaps. The Biomass Policy Framework comprises three stages (Figure 1).

Stage 1: Analysis and direction use statistics, background information and modelling to assess availability and cost for resource efficient domestic biomass supply in the under study geographical area (country, region, etc.) as well as understand relevant market and policies.

Stage 2: Policy aim builds on the context and prioritized value chains, rationalizes policy needs and intends to ensure that any future policy interventions are well integrated into national and regional policy planning. This stage identifies policy-related challenges and gaps that constrain sustainable and resource efficient deployment of the value chains selected under Stage 1.

Stage 3: Policy design creates (future) concepts for a Biomass Policy Framework, tailored to local requirements, supporting the mobilization of domestic, resource efficient biomass value chains, which can create synergies and keep a level playing field with other biomass applications to open opportunities for a sustainable bio-based economy (e.g. through cascading and biorefineries).

The work in each one, including model assumptions and input data, should be communicated to relevant stakeholders involved in policy formation and validated for its credibility and accuracy through consistent participatory process. This will improve the quality and validity of the results and facilitate the acceptance of future policy interventions. The following sections discuss the stages involved in the value chain approach to develop a Biomass Policy Framework and argue that it can be used as a flexible tool adapted to local conditions, allow for qualitative and quantitative analysis of uncertainties and enable appropriate comparisons (Carayannis & Campbell, 2010).

3 | ANALYSIS AND DIRECTION FOR BIOMASS VALUE CHAINS, MARKET AND POLICY

This stage focuses on identifying opportunities within a given geographic setting with respect to domestically sourced biomass value chains, markets and policy.

3.1 | Domestic, resource efficient value chains

Two steps are required to identify and prioritize domestically sourced, resource efficient value chains: (a) assess domestic feedstock options and evaluate their suitability for efficient, commercially mature conversion technologies; and (b) prioritize value chains through stakeholder consultation.

3.2 | Feedstock and conversion technology options

Sustainable feedstock supply can be assessed based on primary production capacities under prevailing climate and ecological conditions. Biomass feedstocks include oil, starch, sugar and lignocellulosic material from agriculture, forestry and biogenic waste sectors. The options for their conversion to bio-based products, energy and fuels depend on their quality traits, and their availability to secure year-round sustainable supply.

Following the assessment of domestic biomass feedstock potentials, their suitability for conversion technologies should be evaluated. Figure 2 outlines the decision tree for prioritizing domestic value chains and understanding the market and policy relevant context of a given region.

3.3 | Prioritizing resource efficient value chains

Prioritization of value chains within their geographic settings will help policymakers focus on resource efficient options that use domestic biomass, contribute to rural and wider economic development and meet overarching climate change, bioeconomy and circular economy targets. Key issues to evaluate include identification of feedstocks which can be sourced without distorting other markets and increasing competition; the efficiency of current conversion pathways; and identification of conversion pathways with best performance in terms of resource efficiency.

Key stakeholders to involve during this participatory process include: national agencies dealing with agriculture, energy, bioeconomy, etc.; government representatives responsible for policy and support interventions along the different stages of

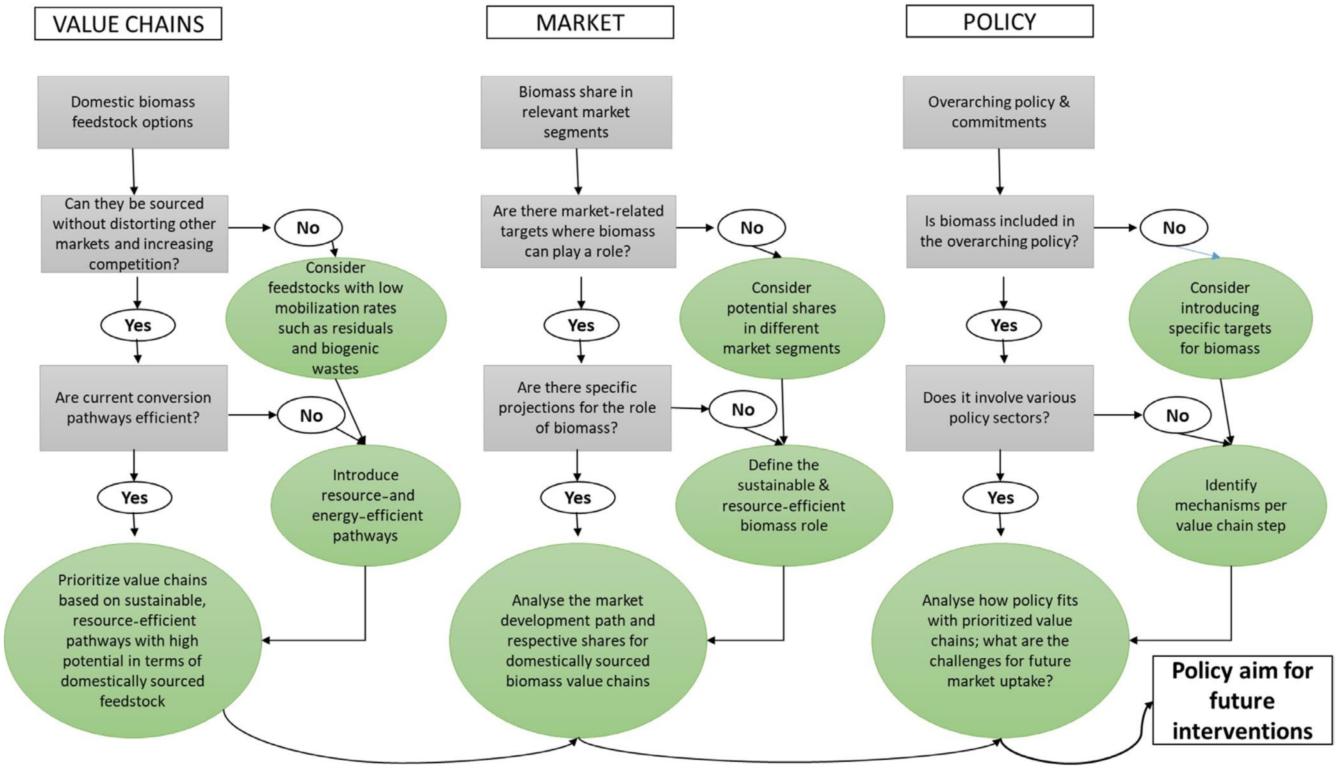

FIGURE 2 Decision tree for prioritizing domestic value chains and understanding the market and policy context

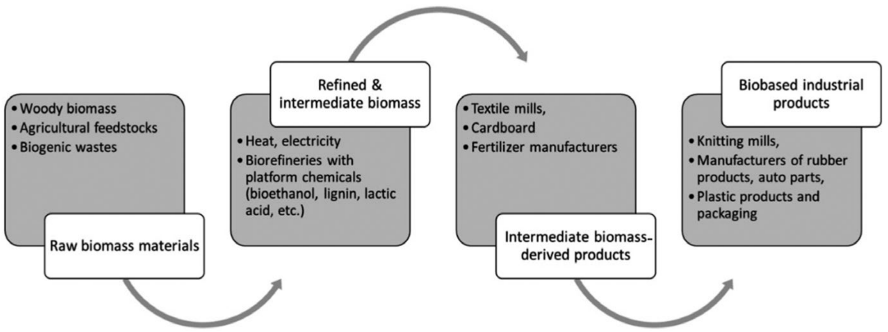

FIGURE 3 Markets for biomass—adapted from Ruamsook and Market (2014)

value chains; research institutions who can contribute data and analysis; and industry actors who can validate the relevance of potential policies and interventions from market perspectives.

3.4 | Markets

Markets including food, materials, fuels and energy and pharmaceuticals use diverse biomass feedstocks. Value chains are expanding and become increasingly complex and interrelated, which is leading to more intense competition for raw materials.

The main goal of analysing the market context in the given geographical setting is to identify market development paths and respective shares for domestically sourced biomass value chains so that the policy can focus on optimal solutions with high market uptake potential.

There are multiple levels of biomass sellers and buyers in the various market segments—see Figure 3. The first level of buyers for raw biomass materials includes the energy sector (heat and electricity plants), biorefineries producing platform chemicals (e.g. bioethanol), the chemical industry and food producers. The second level includes industrial markets of intermediate biomass-derived products, such as those derived from aromatic- and alcohol-based intermediates. Plastic, resin and composite material manufacturers are examples of suppliers at this level while buyers include textile mills, fertilizer manufacturers, etc. The third level entails industrial end markets of bio-based products such as bio-based plastics, textile fibres and customized resins. Examples of buyers at this level are, manufacturers of rubber products, auto parts and packaging.

With growing competition for raw materials, biomass policies must prioritize sustainability and resource efficiency and focus support on market segments where the selected value chains perform best. During the analysis and direction step, early considerations are the current share of biomass in the various market segments and whether there are market-related future targets for biomass. If not, policymakers must consider potential shares in different market segments and further define the sustainable and resource efficient biomass role in these within the foreseeable future.

3.5 | Policy

Biomass offers opportunities to reduce use of petrochemicals and import dependency, mitigate climate change and promote local economies. Initial emphasis by policymakers was primarily on energy uses (heat, electricity, transport), however, ongoing R&D and industrial development plus increased drivers to use renewable raw materials have seen the focus widen to include bio-based chemicals, pharmaceuticals and other materials (Fahd, Fiorentino, Mellino, & Ulgiati, 2012). Consequently, policymakers are now exploring increasingly varied markets and aim to exploit biomass sources sustainably, generate financial returns and achieve varied, high-quality products for consumers.

To assess future policy needs and design interventions that increase market uptake whilst fostering resource efficiency, it is important to review existing policies within different sectors (agriculture, environment, regional economy, etc.) and evaluate their effectiveness for the development and operation of individual biomass value chain stages as well as their interrelation to other policies across the value chain. Figure 4 outlines the relevance of policy domains to value chain stages. Policies within the agricultural sector typically influence land use and primary biomass production. Policies from environment, regional economy and bioeconomy will typically have impacts across all value chain stages. Finally, policies in the transport and energy sectors influence conversion and end use.

Figure 2 outlines questions that need to be addressed. The first question is whether biomass is included in overarching policies. If the answer to this question is negative, policymakers should consider introducing specific targets for biomass. On the other hand, if the answer is positive, the question is then whether biomass is appropriately reflected in the respective policy sectors across value chain stages. A detailed policy overview must be prepared to understand current policy for biomass. This will enable the design of targeted, balanced future interventions that will steer mobilization of low impact, sustainable feedstocks plus facilitate their conversion to products through efficient, innovative technologies.

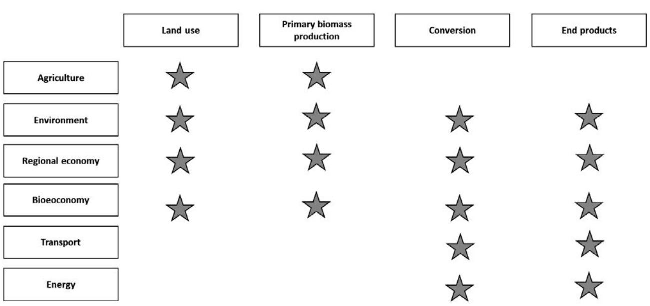

FIGURE 4 Relevance of policy sectors to biomass value chain stages

4 | HOW TO DEFINE THE AIM OF FUTURE BIOMASS POLICY?

The aims of policymakers vary by geographic settings, are strongly related to biomass markets, and influenced by local stakeholder's interests. This stage of the Biomass Policy Frameworkis was designed to provide an overview of challenges and gaps that inhibit biomass deployment in a sustainable and resource efficient manner. These can guide policy design, allow policymakers to rationalize the need for future interventions in the prioritized value chains and plan how to integrate them within existing policies. The challenges and gaps presented below are indicative and aim to illustrate the process of defining the policy aim.

4.1 | Land use for biomass production faces challenges for sustainable planning and exploitation of marginal land types

(i) Land use is a fundamental issue related to biomass production since land availability is limited (Imaz et al., 2017). Emissions from land use change can be significant under some circumstances (Searle & Giuntoli, 2018), however, the simple notion of land use change emissions is not enough to exclude biomass from the list of options for climate change mitigation, bioeconomy and circular economy.

Policy interventions should include a holistic perspective recognizing the multiple drivers and effects of land use change (Perpina Castillo et al.,2018).

(ii) Increasing interest in marginal land (Rentizelas, Tolis, & Tatsiopoulos, 2009) necessitates the development of infrastructure and planning for rehabilitation and the introduction of sustainable management practices (Falcone & Sica, 2019).

Policy must regulate the sustainable use of such land (Van Stappen, Brose, & Schenkel,2011) and secure financing to develop appropriate infrastructure. Capacity building and awareness is necessary to ensure local community and project developers are aware of potential opportunities.

4.2 | Biomass faces challenges for resource efficiency, competition and complex logistics

(i) Resource efficiency and competition are interrelated in circular economy (Pelkmans, Elbersen, Fritsche, Iriarte, & Panoutsou, 2014). Biomass policies must address sustainable raw material provision, account for smooth market operation, local economics and regional specializations as well as efficient conversion to heat, electricity, fuels and bio-based products as viable alternatives to the fossil-based economy.
Policy must consider ways of fostering resource and conversion efficiency in order to produce more energy/bio-based carriers with less consumption of biomass raw materials.

(ii) Biomass logistics (including harvesting and collection, storage, preprocessing or pretreatment and transportation) are often complex especially as the scale and scope of implementation increase. Organizational aspects, variations in availability, storage and backup feedstocks should be assessed during the planning and implementation stages.
Policy support should target financing local biomass supply businesses and capacity building for biomass suppliers and local communities.

4.3 | Market uptake of modern, efficient conversion technologies is hindered by lack of knowledge and inadequate support for advanced conversion pathways

(i) Industries, particularly small and medium sized enterprises, lack knowledge for transition to modern biomass conversion technologies. This limits their market uptake.
Policy must provide guidance for investments in new technologies.

(ii) Modern conversion technologies with higher efficiencies require significant initial investments. Outcomes may be uncertain but both industry actors and funding bodies are typically risk adverse.
Policy must provide improved access to finance for SMEs and industries to share risks and facilitate decision-making.

4.4 | End use has challenges in quality, labelling and consumer awareness

(i) Biomass often comprises diverse, variable quality raw materials. Quality standards and certification are required by large-scale facilities using modern, highly efficient equipment.

TABLE 1 Policy-related challenges, relevant gaps and aim for future policy

	Challenge	Policy relevant gaps	Aim for future policy
Land use	Sustainable land use	Land use is often not well represented in bioenergy or bioeconomy policies (Holmatov, Hoekstra, & Krol, 2019)	Sustainable land use practices
	Exploitation of marginal land	Legislation often has ambitions to exploit such land but lacks targeted interventions	Exploitation of marginal land (Banja et al., 2019)
Biomass production	Resource efficiency	Current legislation is often ambiguous	Promote resource efficiency through targeted financing per value chain
	Competition for biomass feedstocks	Lack of targeted financing premiums for feedstock with low mobilization rates (e.g. residues and biowastes)	Address competition
	Complex logistics (Rentizelas et al., 2009)	Lack of knowledge and access to capital for handling multiple biomass feedstocks (Brandao, Canals, & Clift, 2011)	Improve infrastructure for logistics
Conversion	Low awareness of SMEs and industries for innovative, efficient technologies (Bonfante et al., 2017)	Lack of knowledge and access to information	Improve knowledge and access to information
	Advanced technologies lack secure financing (Malico, Pereira, Gonçalves, & Sousa, 2019)	Lack of tailored financing	Improve access to finance to SMEs and industries
End use	Residual and biogenic wastes are often of low quality and lack standards	Quality specifications for less utilized residual and biogenic waste streams are limited or do not exist	Ensure quality of residual and biogenic waste biomass streams
	Bio-compounds are not clearly mentioned in products and services	Labelling procedures lack detailed specifications	Improve biomass labelling
	Consumers lack trust in biomass sustainability (Russo, Confente, Scarpi, & Hazen, 2019) and do not fully understand its benefits	Limited information for the wide range of products and services that are related to biomass and their benefits including environmental sustainability	Clear communication messages for biomass value chain benefits (Panoutsou, 2008)

Policy must develop standards and certification procedures, especially for residual and biogenic waste streams in order to ensure their quality.

Labelling of products and services with bio-components needs improvement to ensure consumers are fully aware when making choices.

Policy must deliver regulations for labelling and product quality monitoring procedures.

End consumers lack awareness and information on the wide range of products and services that are related to biomass and may often misunderstand their potential benefits including sustainability.

Policy must deliver robust, evidence-based messages and continuously updated information through end consumer awareness campaigns and targeted capacity building programmes at the implementation level.

Table 1 outlines the policy-related challenges, relevant gaps and suggests aims for future policy to alleviate challenges and resolve gaps across the value chain stages.

5 | HOW TO DESIGN A DEDICATED BIOMASS POLICY?

A dedicated biomass policy with interventions, integrated across the different value chain stages, can ensure the uptake of biomass value chains that are both suitable for the specific geographic setting and help the successful delivery of increased biomass shares in sectors such as energy, bioeconomy, etc.

The policy design stage identifies a set of policy interventions which can act in an integrated way across the prioritized value chains. A mix of interventions should be considered when designing policy across the biomass value chain, in order to address the variable challenges and gaps and allow optimal performance at all stages. Categories of interventions include:

- Regulations that define rules to control actions. These include quota obligations, product standards, tax exemption and reduction, targets and qualifying criteria for incentives, feed-in-tariffs, green procurement, etc.
- Financing mechanisms that support investments and operation of value chains. They include feedstock premiums, capital grants, technology and feedstock-related premiums, tax incentives, user charges, research funds, etc.
- Information provision mechanisms that include soft actions for the promotion and dissemination of best practices and successful lessons learnt, capacity building, awareness raising, etc.

Table 2 outlines relevant mechanisms and their expected added value for the policy aims identified in the previous section (Table 1). The main points are summarized below.

5.1 | Land use

By developing sustainable land use policies and ensuring their continuous implementation, the direct and indirect land use impacts (Van Stappen et al., 2011) can be better addressed and monitored (Di Lucia, Ahlgren, & Ericsson, 2012). This will increase confidence both in industry (for planning their future investments) and in public (reducing scepticism over sustainable biomass practices).

Establish and reinforce the legal certainty for marginal land use will increase opportunities for landowners, farmers and foresters (to produce biomass feedstocks) but also for industry (to broaden their feedstock supply options).

5.2 | Biomass production

Addressing competition for biomass through policy that targets resource efficiency will influence positively the use of natural resources such as land and water whilst broadening the feedstock baseline.

Improving logistics will foster the development and improve operational capacity of biomass trade centres and hubs. The industry will benefit from uniform, good quality material, contractual arrangements will be simplified and domestic biomass supply flows at the given geographical setting will be enhanced.

5.3 | Conversion

By supporting industries and SMEs towards their transition to a sustainable, low carbon bioeconomy, biomass flows from process residues and biogenic wastes will be mobilized, and carbon footprints will be improved.

Support for new, highly efficient technologies industries will improve access to capital for SMEs and industries.

5.4 | End use

By developing standards and certification procedures for residual and biogenic waste feedstock types the mobilization of unused biomass stream will increase and competition for wood will be reduced gradually.

Labelling improves transparency both for consumers and industrial actors and labels can be a suitable tool for creating confidence in bio-based products. Comprehensive standards are, however, required and they should be based on specific criteria reflecting performance along the whole value chain.

Finally, providing evidence-based information for public will promote and maintain trust in biomass and facilitate rural, economic and industrial development.

TABLE 2 Policy mechanisms that can facilitate the aim of future policy and their expected added value

	Aim for future policy	Relevant mechanisms	Added value
Land use	Sustainable land use practices	Regulations framing sustainable land use and relevant practices should be differentiated. Of relevance are regulations dealing with nature conservation, soil and groundwater protection (Wiesmeier et al., 2019), regional planning etc. Investment subsidies Capacity building	Sustainable, optimized use of land Improved access to finance for landowners and project developers Rehabilitation of marginal land and increased opportunities for improved landscapes in rural areas
	Exploitation of marginal land (Banja et al., 2019)	Regulations for the sustainable use of marginal land Financial support to develop the infrastructure Capacity building and awareness activities for local community and project developers	
Biomass production	Promote resource efficiency through targeted financing Address competition	Feedstock premiums with higher support for currently unused biomass streams	Mobilization of currently unused feedstock streams. Reduced competition for commonly used biomass feedstocks such as wood
	Improve infrastructure for logistics	Loans or credit lines for biomass trade centres Capacity building for biomass suppliers and local communities	Increased feedstock options to provide year-round biomass supply
Conversion	Improve knowledge and access to information	Capacity building and awareness activities for SMEs and industries	Provide opportunity for industries, SMEs and local actors to adopt new technologies and increase biomass market uptake Increased mobilization of unused feedstocks
	Improve access to finance to SMEs and industries	Tailored financing for resource efficient technologies Joint ventures between public and private institutions	Reduce financing risk of new technologies, improve their market uptake and respective carbon reductions
End use	Ensure quality of residual and biogenic waste biomass streams	Standards and certification procedures	Increase mobilization of unused resources streams and reduce competition
	Improve biomass labelling	Regulations for labelling requirements and product quality monitoring procedures	Develop the market for further deployment of the biomass feedstocks
	Clear communication messages for biomass value chain benefits	Public awareness campaigns (Sijtsema et al., 2016) Targeted capacity building programmes	Promote the well-being of environment as well as local population

TABLE 3 Features of contrasting paradigms for biomass policy within single sector target setting compared to the value chain approach (Elghali, Clift, Sinclair, Panoutsou, & Bauen, 2007; Rosenhead & Mingers, 2001)

Traditional paradigm of single 'sector' target setting	Paradigm of the value chain approach
The 'new' policy agenda is based on delivering sector-specific targets	Challenges and gaps are identified jointly with stakeholders and consider geographically specific capacities and context. This ensures policy focus on appropriate value chains from the outset of policy reform.
Multiple objectives that are subjected to trade-off on a common scale with other non-biomass options	Multiple objectives are clearly recognized per value chain stage and new policy targets optimal performance, sustainability and resource efficiency
Overwhelming data demands, with consequent problems of distortion, generalization, data availability and data credibility	Narrow set of performance indicators, tailored to reflect cross value chain performance, facilitate resource efficiency and sustainability
People are treated as passive recipients	Stakeholders are engaged throughout the value chain policy analysis with clear roles (Table 1) and benefits (Table 2)
Attempts to abolish future uncertainty, and pre-take future decisions	Accepts uncertainty and facilitates bottom-up decision-making which includes future options that capitalize on local context and capacities, safeguard sustainability and facilitate resource efficiency

6 | WHY CONSIDER THE VALUE CHAIN POLICY APPROACH FOR A DEDICATED BIOMASS POLICY FRAMEWORK?

This opinion paper argues that despite the increased attention biomass has as renewable, non-fossil raw material, in many cases the market uptake of domestically sourced, resource efficient value chains has been fragmented and is suboptimal. It reiterates that a value chain policy approach can better stimulate resource efficient uptake of biomass and facilitate delivering overarching sector targets in low carbon energy, bioeconomy and circular economy. This approach will allow policymakers to design interventions across the different stages of value chains and exploit advantages within specific geographic settings and consequently achieve higher market uptake.

Table 3 outlines important features of the contrasting paradigms for the two approaches while Table 4 uses the case of low carbon heat for biomass to illustrate the weaknesses of single sector target setting for the uptake of sustainable, resource efficient biomass value chains and the respective

TABLE 4 The value chain approach of the Biomass Policy Framework compared to sector-specific targets for low carbon biomass heat

Land use	Biomass production	Conversion	End use
Sector target: Promotion of low carbon energy in the heat sector			
No planning on sustainable land use linked to biomass production	No prioritization of domestically sourced feedstocks	Technology, market segment and implementation scale neutral	Only large-scale industries are aware of high-level targets and have financing options for such transitions to low carbon energy systems
Weaknesses: (a) direct or indirect land use changes, (b) displacement effects, (c) negative perception on biomass sustainability	*Weaknesses*: (a) reduce mobilization from local biomass; (b) fewer opportunities for local farmers, foresters and landowners; (c) increased imports of commonly used woody feedstock types result in strong competition among sectors	*Weaknesses*: failure to steer biomass market uptake at scales and market segments (domestic, tertiary, etc.) where the energy system owners lack knowledge and easy access to finance (e.g. single houses with low income, schools, hospitals and public buildings in rural areas with access to low cost biomass feedstocks)	*Weaknesses*: (a) Large-scale applications without detailed planning for land and biomass production increase competition for raw material and risks for deforestation, indirect land use changes, etc.; (b) missed opportunities at decentralized level for small- and medium-scale applications
Interventions: It is unlikely that there will be any interventions in place for land use in relation to biomass	*Interventions*: It is unlikely that there will be any interventions in place for mobilization of low impact feedstocks	*Interventions*: Targets for GHG reductions- Finance high conversion efficiency	*Interventions*: GHG emission reduction targets for large industries
Value chain approach for dedicated biomass policy in the heat sector			
Guidance for sustainable land use planning and monitoring including opportunities to rehabilitate marginal land	Focus on feedstock supply opportunities that can deliver benefits to the local community	Focus on highly efficient technologies that are suitable to use domestic biomass feedstock options	Market segment analysis to evaluate the sustainable & resource efficient biomass role for selected value chains at a given geographic setting
Strengths: (a) resource efficient and sustainable land use, (b) rehabilitation of marginal land	*Strengths*: (a) mobilize low cost residual and biogenic waste domestic feedstocks, (b) increase income opportunities for local communities, (c) minimize competition	*Strengths*: (a) tailor support to specific market segments that are suitable to local conditions and end users, (b) create opportunities for small-scale local value chains	*Strengths*: policy will target project scales that are feasible for domestic biomass availability and local end use sectors
Interventions: Subsidies for land rehabilitation	*Interventions*: Feedstock premiums, easy access to capital for biomass supply companies; Capacity building for biomass suppliers and local communities	*Interventions*: Capacity building and awareness; targeted financing per scale implementation and market segment	*Interventions*: Detaxation, loans for specific market segments

strengths of using the value chain approach of the Biomass Policy Framework.

7 | CONCLUSION AND POLICY IMPLICATIONS

Policies are in place to promote increased use of biomass (European Commission, 2018; European Union, 2018) but progress is slow compared to known potentials. This can be partly attributed to the fact that policymakers have focused to date on biomass shares within sector-specific targets rather than providing integrated support across the stages of biomass value chains and exploiting specific advantages related to their geographic settings.

Several studies (Banja, Sikkema, Jégard, Motola, & Dallemand, 2019; Lipp, 2007; Schmidt, Helme, Lee, & Houdashelt, 2008) focus on the effectiveness of different biomass policies in meeting sector-specific targets—with energy and climate change being the most frequently analysed. This opinion paper argues for a paradigm shift, and use of the value chain approach, whereby policymakers complement sector-specific focus with dedicated biomass policies that exploit opportunities for resource efficient value chains and leverage specific strengths within their respective geographic settings. This approach will achieve higher market uptake of sustainable, domestic biomass, mitigate raw material competition and facilitate rural, industrial and economic development and simultaneously deliver higher biomass shares within sector targets.

The implications of this work are relevant to policymakers whose remit includes biomass at all levels of government. The approach is particularly appropriate with varied industries increasingly exploring biomass feedstocks as sustainable, fossil fuel alternatives, which is leading to more expansion of value chains that are more complex and interrelated.

A limitation is that the value chain approach is not a representation of the whole economy, but an in-depth description of a specific segment of it giving only a partial vision of the economy and requiring a large amount of data. To overcome this issue, this paper suggests the use of a relatively small number of appropriate metrics to assess technical, environmental, economic and socio-economic impacts (Bellù, 2013; Dale, 2007). Additional metrics can be considered during the policy impact assessment (Loulou, Remme, Kanudia, Lehtila, & Goldstein, 2005; Tasios, Apostolaki, Capros, & De Vita, 2013; van Stralen, Dalla Longa, Ros, & Uslu, 2013) to allow consolidated, comparative evaluation of the full performance of the biomass value chains for different time horizons.

A strong merit of the value chain approach is the fact that it is a flexible tool which is easy to adapt. It facilitates the delivery of a dedicated biomass policy through understanding of how interventions, integrated across the biomass value chain stages, can overcome challenges and resolve gaps in a more effective way than isolated sector-specific policies.

The work presented in this paper aims to guide future biomass policymaking. The described analysis illustrates how this approach can empower policymakers to better capitalize on the strengths of value chains within their geographical setting and directly address prevailing challenges and policy relevant gaps. Systematically identifying these challenges and gaps can then guide policy reform, steer implementation of sustainable value chains and increase biomass market uptake.

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