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A "system dynamics perspective" of bioenergy governance and local, sustainable development

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Abstract

This study investigates the governance of bioenergy systems (BESs) and how it influences the bioenergy policy process and local sustainable development. The study compares the BES in Emilia Romagna and Hedmark. At first, bioenergy was expected to mitigate climate change and to tackle the crisis of the primary sectors and related industries. However, bioenergy policies were not equipped to address cross-sectoral and multilevel issues. Therefore, they failed to secure the local, sustainable development. Critical weaknesses lie in BES governance. Actors' discourses, rules, and power issues form a complex structure that influences the bioenergy policy process and its outcomes. The study relies on systems thinking and system dynamics, and the pathways approach. It uses the system archetypes to investigate the bioenergy policy feedback dynamics and how to leverage local, sustainable development. Results show that power relations and social opposition are critical to a policy change that best secures local, sustainable development.

KEYWORDS

bioenergy system, feedback, governance, policy analysis, systems thinking

1 | INTRODUCTION

This study investigates the governance structure of the bioenergy system (BES) and how it affects the bioenergy policy process evolution and local, sustainable development in two regions, that is, Emilia Romagna (Italy) and Hedmark (Norway).

A BES is a system where human and ecological elements interact. Humans perceive the environment around them and its dynamics and act according to their values, understandings, and goals. These human actions impact on the environment and trigger biological, chemical, and physical reactions, whose consequences (e.g., changes in biodiversity and carbon sink) influence the human actors' perceptions and understandings of the ecosystem around them. In this context, governance is the regulating structure of the BES, that is, the conditions or institutions for the ordered rule and collective action. This structure emerges from the interrelations of the actors' framings of bioenergy development, rules of the game, and power relations.

The goal of the study is twofold. First, it aims to shed light on how the governance structure of the BES triggers the feedback dynamics that affect local, sustainable development by focusing on the case of bioenergy. Second, the study aims to contribute policy analysis and policymaking with a better understanding of how these feedback dynamics shape the policy process evolution,

Abbreviation: BES, bioenergy system.

thus impacting on local, sustainable development. On this basis, the study will give inputs on how to enable a change in mindset and policymaking processes. The main research questions of this paper are as follows: How does the governance structure influence the bioenergy policy process evolution and local, sustainable development? How can we leverage the governance structure to better secure sustainable local development?

Sustainable local development is intended as the interconnected social (including economic) and environmental benefits of bioenergy development. There is not a shared definition of sustainability rather than that by the Brundtland Commission. Therefore, the use of the term *sustainability* refers to the expected benefits of bioenergy development as outlined in the Organisation for Economic Cooperation and Development (OECD, 2010, 2012) reports and the informants' expectations of the social and environmental benefits of bioenergy development. In this study, *sustainability*, *sustainable outcomes*, and *social–environmental benefits* are used interchangeably.

In general, this study draws on the idea that bioenergy is a land-based activity. Namely, it relies on land-related resources such as soil, water, microbes, and feedstock. Thus, the diffusion of bioenergy is a contextually embedded process that significantly depends on available natural, human, infrastructural, technological, and institutional resources (Batel, Devine-Wright, & Tangeland, 2013; Bryden, 2010; Bryden, Cavicchi, Kvakkestad, Prestvik, & Refsgaard, 2017; Bryden & Gezelius, 2017; Bryden, Gezelius, & Refsgaard, 2013; Cavicchi & Ely, 2016; Dale et al., 2010; Mårtensson & Westerberg, 2007; OECD, 2012). BESs are complex and involve a set of social and ecological dimensions linked via feedback processes that span at different time–space scales. These feedback cross-scale relations imply that the benefits of bioenergy at the local level may not result in benefits at other scales and vice versa.

Moreover, the time dimension challenges the notion of simultaneous and fast-delivered social and ecological improvements, because benefits on the two aspects may happen at different times and with delays. Social opposition has been one of the main unintended consequences of these challenges (Adams, Hammond, McManus, & Mezzullo, 2011; Carrosio, 2013; Cavicchi, 2018; Dale et al., 2010; Sjølie, Trømborg Solberg, & Bolkesjø, 2010).

A core aspect of social opposition is that actors perceive and reckon with the pros and cons of bioenergy development with a time delay that must be added to the time delay with which material processes happen (e.g., local heating, greenhouse gas emissions, biomass production, and extraction, and smells and emissions from plants). First, this time delay implies that by the time the effects of bioenergy production are perceived, the other circumstances might have changed already (e.g., plant and biomass management practices that contain the adverse effects). Second, local effects have repercussions on other spatial scales; for instance, the effects of increased traffic in rural areas due to the transport of biomass from far away will impact on national and global CO_2 emissions, whose causal relations are difficult to establish and will nonetheless be registered only at a later stage via statistical analysis. Often, local inhabitants throughout the globe have reacted by demanding a change in policies and planning approaches to stop the "harmful" effects of bioenergy production. These demands resulted in sudden changes in policy schemes (e.g., removal of financial support) that have nearly stopped the diffusion of bioenergy. Evidence shows that these dynamics are the result of interdependent governance structures and processes operating at different but interrelated scales and times. Therefore, on the one hand, we need to better understand the interdependence of social and environmental processes across scales (e.g., Cavicchi, 2016, 2018; Cavicchi & Ely, 2016); on the other hand, we need to look at the governance of the BES to understand what structural dynamics affect sustainable local development. On the basis of a previous within-case analysis (Cavicchi, 2016; Cavicchi, 2018; Cavicchi, Bryden, & Vittuari, 2014; Cavicchi & Ely, 2016; Cavicchi, Palmieri, & Odaldi, 2017), evidence shows that despite the contextual differences (e.g., geography, adopted technology, and biomass type and policies), the two regions share similar declining bioenergy production trends, policy objectives, discourses, and power relations. Thus, this comparison has the potential to shed light on the patterns of behavior of bioenergy governance configurations that impact on sustainable local development.

The study relies on the idea that the BES boundaries are the result of the observer's perceptions of real-world events as influenced by the surrounding environment (Cavicchi & Ely, 2016; Leach et al., 2007; Midgley, 2000). Specifically, the BES boundaries are a result of the researcher's interpretation of the actors' understandings of bioenergy development and sustainability (subjective boundary) and the biophysical, technological, environmental, and human elements (objective boundary). The assumption is that these understandings are influenced by the surrounding environment, that is, both the biophysical and sociocultural contexts. The governance of the BES is the regulating structure composed of human elements (i.e., rules, power relations, and actors' understandings/perceptions) that trigger internal processes and that allow the system to (mis)perform the assigned functions, that is, to deliver sustainable local development.

2 | CONCEPTUAL FRAMEWORK

This study relies on systems thinking and system dynamics (Checkland, 1981; Senge, 1990; Lane, 2001a; Cavana et al., 2019; Wolstenholme, 1999, 2003; Lane & Kopainsky, 2017; Lane, 2000; Lane, Munro, & Husemann, 2016), and the pathways approach (Leach, Scoones, & Stirling, 2010a; Leach, Stirling, & Scoones 2010b; Scoones et al. 2007; Cavicchi & Ely, 2016; Lamine, 2011; Byrne et al., 2011) to study the policy feedback process and how the governance structure influence its dynamics. The policy feedback process field explains that the policy designs are influenced by, often dominant actors, and implemented by a combination of these and other marginal actors. The outcomes of the implementation process trigger reactions that if channelled into the decision and policymaking, may have the power to lead to a change/reform or stability of the policy design (Weible et al., 2017; Pierson, 1993; Jordan & Matt, 2014). The systems thinking tradition enriches the policy feedback approach by providing an understanding of how different subjective and objective elements are interconnected and influence the pathway of bioenergy development. This systems thinking tradition argues that "[…] people, through self-consciousness and language, have the ability to conceptualize themselves and the systems that they are part of—they exist in a world of meaning and signification. This means that we cannot just take for granted, from the outside, the nature of a particular social system or social interaction but have to engage with the participants and become active observers" (Mingers, 2014, p. 6). In other words, humans and social groups hold particular understandings of the world events, which they influence with their actions and through social interaction.

Thus, I understand systems as social constructs or tools that help in exploring and better understanding the feedback relationship between the "real world" (made of material things, such as trees, natural processes, houses, and technologies) and the humans' understandings of it (perceptions, values, visions, and habits). For instance, in the BES, the social and environmental dimensions are interconnected and interdependent; that is, they mutually influence each other (Biggs et al. 2015). On this, the pathways approach argues that systems are human constructs that encompass both the subjective and objective dimensions. A "system" "[…] consist[s] of social, institutional, ecological and technological elements interacting in dynamics ways" (Leach et al. 2010b, p. 43). The boundaries of the system, that is, rules, power relations, perceptions, and institutional biophysical, material, and technological elements, are defined in the interdependence and continuous interactive dialogue between subject and object. In this feedback relationship, the framings of the real world arise and shape a particular development pathway of the sustainability transition processes (Leach et al. 2010, 2010; Cavicchi & Ely, 2016). These elements together are defined as systems and show how the interrelation of social and ecological elements evolve together.

This understanding of systems emphasizes the importance of defining the system's boundaries, that is, a first-order boundary definition on the object and a second-order definition on the subject(s) and the environment that influences the subject(s)'s perceptions of the object (Midgley, 2000). For instance, the subjective boundary of the BES includes both the stakeholders' and my understandings of bioenergy development in the light of social and environmental benefits. Specifically, what are considered as the social and environmental benefits or the "bads" of bioenergy development is a matter of the actors' (often viewed as a social group) and my (the researcher) definition. Nonetheless, this definition is influenced by international debates and documents, for instance, the work of the Brundtland Commission and OECD studies, or national and local discussions. Part of this second order—the subjective boundary—is also the explanation of how bioenergy development unfolded over time and thus the causal processes that characterize the bioenergy social–ecological system in the two case study regions. A lot has been said on this in other work (see Cavicchi, 2016; Cavicchi, 2018; Cavicchi & Ely, 2016).

Moreover, my understanding of social sustainability refers mainly to the localities where bioenergy is adopted and encompasses the participatory and inclusive factors as ways to empower those that are usually excluded from the dominant actors (Bryden et al., 2017; Cavicchi et al., 2017). I also tended to disregard the factor of technological development because it tends to overlook the environmental side and its interrelations with the social elements. This conception was influenced by the work and approach of my colleagues at the Norwegian Institute for Agricultural Economics Research (NILF).

The first-order boundary judgment stands on the second-order boundary judgment. The object of the study is the BES. The BES includes biophysical, technological, environmental, time, and human elements. I studied the BES in the two regions within a period of approximately 15 years (i.e. between beginning of the 2000s and 2015). The boundary thus includes the territorial and administrative dimension defined as "regional" territory. The regional seems to exclude the national and international actors and policies, but from a policy feedback perspective, I considered how local dynamics impact on the national and regional policy design. Biophysical and other material elements within this boundary are, for instance, soil nutrients and biodiversity, CO_2 emissions, bioenergy plants, demand and supply of bioenergy, and energy price. This boundary also includes policies (or rules of the game). Policies are an output of human actions, but they are formalized into documents, thus why I include them in the objective boundary. The BES also excluded research and innovation in connection with bioenergy technology development.

The rules, power relations, and actors' perceptions are the structural elements that influence the bioenergy policy process and local, sustainable development. These structural elements form the governance structure of the BES. Lebel et al. (2006) write that governance is "[…] the structures and processes by which societies share power, shapes individual and collective actions" (p. 19). In this, power has a dedicated place as a dimension that shows the "[…] (in)capacity of actors to mobilize resources and institution to achieve a goal." The underlying idea is that two actors exercise a different type of power to and over X resources (Avelino, 2017, p. 508). Notably, if A exercises more power than does B, it does not mean that B does not have any power at all or that B is wholly subjected to A. B might exercise a different power that A cannot, thus having some independence from A (Avelino, 2017; Avelino & Rotmans, 2009; Avelino & Wittmayer, 2015).[1] This dynamic notion of power relations informs the analysis of the governance structure, its influence on the evolution of the policy process, and local, sustainable development (e.g., conflicts between small and large forest owners).

To conclude, the study refers to the system archetypes as conceptual tools to explain how the governance structure influenced the policy process and local, sustainable development (Senge 1990; Senge et al., 2010; Cavana et al., 2019). The study considers the archetypes as patterns of behavior or mental models in the sense of the ideal type of Weber. Namely, archetypes are a way to simplify empirical information (or social reality) by identifying the most common patterns of behavior within systems as seen by the observes (Senge et al., 2010). Archetypes can also be used to make a hypothesis and analyse the underlying patterns of behaviors within systems and show the (dis)advantages of nonsystemic solutions (Wolstenholme, 2004). Although archetypes may be theoretically weak, they are useful analytical tools that represent the results of qualitative and quantitative systems research (Wolstenholme, 2003). In this study, the archetypes show causal links between events and the overarching governance structure that influence the policy process pathway over time (Cavana et al., 2019; Wolstenholme, 2003; Wolstenholme, 2004; Leach et al. 2010b; Cavicchi & Ely, 2016). The rationale for identifying the governance structure is that behind each process, there are rules, power relations, and actors' understandings that shape the way the processes unfold (e.g., Cavana et al., 2019). For instance, in the Emilia Romagna case, behind sugar production, there are big-industrial farmers, whereas behind biogas production, there are both big- and small-scale farmers and other kinds of entrepreneurs. This picture suggests that there might be power struggles between these actors due to a different degree of control over key resources for biogas production.

[1]There is not a common definition of power and power relations. However, this study relies on the work of Avelino and other scholars who have extensively worked on power and related issues in sustainability transitions. *Resources* refers to those that can be owned (e.g., natural resources, human, mental, monetary, artifactual resources, and financial stocks), thus making a distinction with "relations, rules, laws, culture, institutions or traditions that come to play in the act of mobilizations starts, i.e. as soon as power is exercised" (Avelino & Rotmans, 2011, p. 798). A key feature of resources is that they are in themselves power neutral; "they only become power-laden when they are mobilized by actors" (Avelino & Rotmans, 2011, p. 798).

2.1 | Introduction to Emilia Romagna and Hedmark contexts

Emilia Romagna is located in the northeastern part of Italy (Figure 1). The region hosts a significant part of the fertile Padana Plain (Po Valley) that for decades provided land to farmers and livestock and an Apennine part rich in forests (see Cavicchi, 2016). The regional environment is different in the mountain and plain areas. The forests in the Apennine contribute to biodiversity conservation and carbon capture. The plain areas are less rich in animal and plant species and are a source of high greenhouse gas emissions. The most polluting macrosectors are transports, agriculture, heating, and industrial combustion, which are all located in the Padana Plain (Agenzia Regional per la Protezione Ambientale (ARPA) Emilia Romagna, 2016). Agriculture is supposed to contribute to the regional environment via a better management of fertilizers and pesticides use, regulations to preserve plant and animal biodiversity, making water consumption more efficient, reducing soil erosion, using and producing renewable energy with agricultural residues, reducing greenhouse gas emissions from ammonia, and improving the forest carbon capture capacity (Direzione Generale Agricoltura E.R, 2007; ARPA Emilia Romagna, 2016).

Agriculture is still a relevant sector in the regional economy, accounting for 2.77% of the regional value

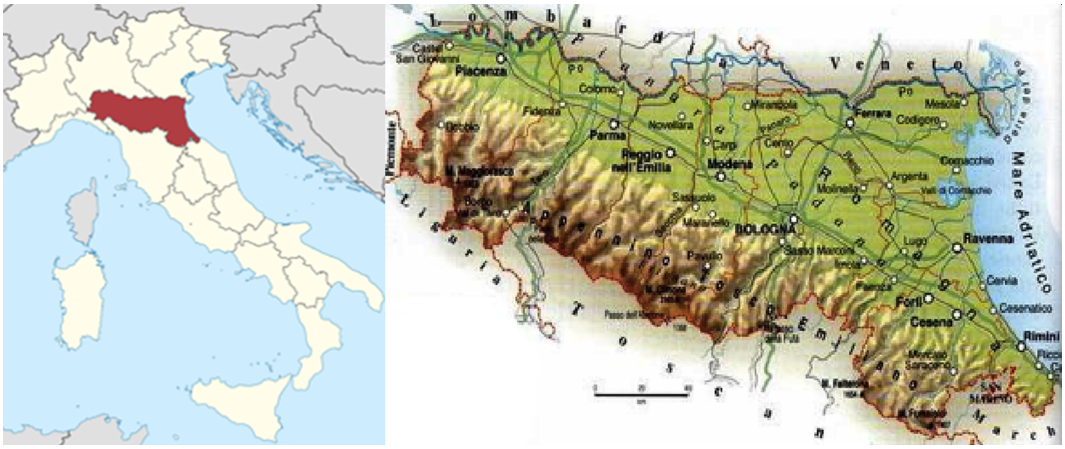

FIGURE 1 Emilia Romagna region [Colour figure can be viewed at wileyonlinelibrary.com]

added in 2013 and showing a steadily increasing trend from 2011 (2.49%). Until the 2004 Common Agricultural Policy reform, which profoundly affected the sugar sector in Italy, Emilia Romagna was the leading region in Europe in the sugar sector (16 sugar factories). Emilia Romagna's energy system relies on natural gas for both electricity and heating production.

Hedmark is located in the southeastern part of the country on the borders with Sweden. The Glomma River divides Hedmark into two areas Østerdalen (from Os to Elverum municipalities in the northern part of Hedmark), dry and cold, and Glåmdalen (from Våler to Sør-Odal in the southern part of the County), warmer and more humid (Figure 2). The area around the Glomma is characterized by rounded mountains, pine and spruce forests. The rest of the County—western part—lies beside Mjøsa, a big lake between Oppland and Hedmark County. The area surrounding the Mjøsa Lake is the most fertile agricultural area. The County's forested areas constitute 13.8% of the national forest area and cover approximately 60% of the county land (Fylkeskommune, 2014; Statistik Sentralbyrå (SSB), 2015a, 2015c). Thus, forestry has been a vital industry in the region, providing jobs and income to local communities, although it has been on the continuous decline since the 1970s. Hedmark also has the largest and most productive forest properties in the country and the highest number of employees in forestry compared with the national figures (Norwegian Institute for Agricultural Economics Research, 2012; SSB, 2015f, 2015g, 2015d, 2015a, 2015c, 2015e). However, the most common property size is very small, that is, 25–99 ha. In 2013, Hedmark accounted for the largest share of forest properties with commercial round-wood removal on national base (18%) (SSB, 2015a, 2015b, 2015c).

The most polluted areas are around cities. Road traffic is the primary cause of greenhouse gas emissions according to the Fylkesmannen statistics (Jacobsen, 2019). Agriculture is the second most polluting sector in the County.[2] The forests carbon capture capacity strongly mitigates these emissions.[3] The County's energy system is based on hydropower as in the rest of the country with the few exceptions of oil and natural gas used for heating production in public buildings. Oil extraction is the leading national industry.

3 | METHODOLOGICAL ASPECTS

This study applies qualitative and comparative case study methodology to investigate how the BES can secure sustainable local development within the bioenergy transition (George & Bennett, 2005; Mjøset, 2006; Mjøset, 2009). It originates from an in-depth within-case study analysis[4] (Bennett & Elman, 2006) of bioenergy development in Emilia Romagna (Italy) and Hedmark (Norway; Cavicchi & Ely, 2016; Cavicchi, 2016; Cavicchi, 2018). The within-case analysis was necessary to investigate the causal processes of bioenergy development in the two

[2] https://www.fylkesmannen.no/nb/Hedmark/Landbruk-og-mat/Miljotiltak/Klimatiltak-i-landbruket/?id=92625

[3] https://www.fylkesmannen.no/nb/Hedmark/Landbruk-og-mat/Skogbruk/Skog-og-miljo/?id=7529

[4] In the within-case analysis, I drew on systems thinking, the transitions governance approach, and the pathways approach to study bioenergy development in Emilia Romagna and Hedmark. I conceived systems as social constructs and as a result of actors' mental models, and I used causal loop diagramming to draw the feedback links between social and environmental processes. In the within-case analysis, I also outlined the governance structure that underpins the bioenergy system development. However, I did not explore the links between the causal loops and the governance dimensions (i.e., power relations, rules, and actors' perceptions/understandings). See Cavicchi (2016, 2018) for the details.

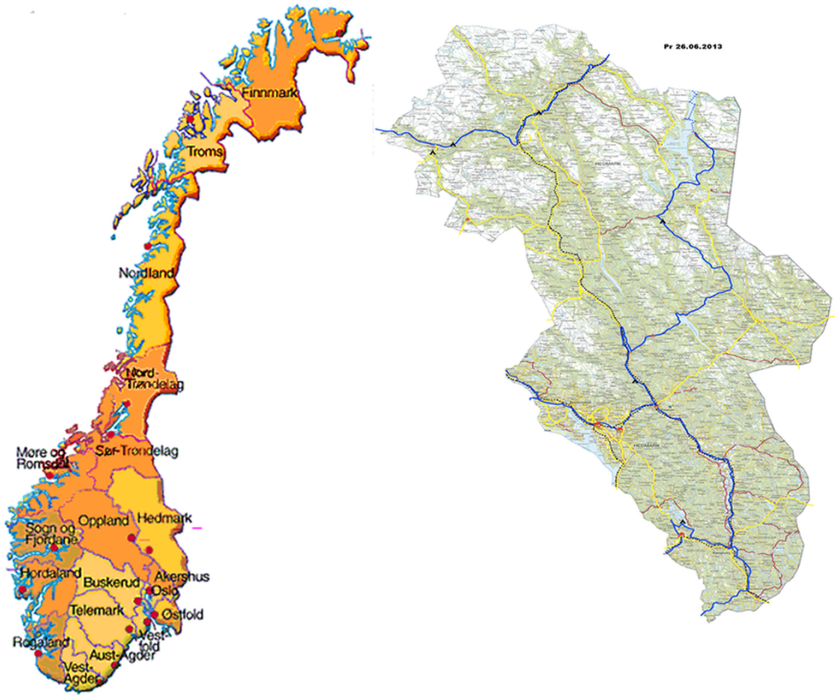

FIGURE 2 Hedmark County [Colour figure can be viewed at wileyonlinelibrary.com]

case study regions and uncover the dynamics that jeopardize the delivery of social and environmental benefits. The results of the within-case analysis are the basis for the comparison. More details on the methods and data sources used to carry out the within-case analysis can be found in Cavicchi (2018a, 2016), Cavicchi and Ely (2016) and Cavicchi et al. (2017).

The case studies were chosen for comparison because of the similarities in the early dynamics of bioenergy development that in combination with the evident contextual differences (see below for details) can shed light on the elements of the governance structure that influence the evolution of the policy process and local, sustainable development. More precisely, in both regions, the bioenergy discourse evolved around three common factors:

1. the crisis of the primary sector and related industries;
2. EU renewable energy and climate change targets; and
3. dependence on one primary source of energy and its price.

The differences are as follows:

1. the fact that Hedmark has a more inclusive public policy system than has Emilia Romagna;
2. land and forest property rights; and
3. type of bioenergy technology adopted.

These factors led to different social, economic, and environmental outcomes, although, eventually, bioenergy adoption consistently slowed down in both cases. The assumption is that there could be similar dynamics within the BES governance structure that explain the sudden slow-down of bioenergy development.

The comparison builds on the findings of the within-case analysis (Cavicchi, 2016; Cavicchi, 2018; Cavicchi et al., 2014; Cavicchi et al., 2017; Cavicchi & Ely, 2016), the governance dimensions and interrelations between them highlighted in the pathways approach and power in transitions approach (Leach et al., 2007; Byrne et al., 2011; Cavicchi & Ely, 2016; Leach et al., 2010a; Stirling, 2014; Avelino & Wittmayer, 2015; Avelino, 2011; Avelino, 2017), and the system archetypes (Braun, 2002; Cavicchi, 2018; Kim, 1997; Senge et al., 2010; Wolstenholme, 2004; Cavana et al., 2019). The three governance dimensions are actors' framings, rules of the game, and power relations (Smith & Stirling, 2010; Smith, Stirling, & Berkhout, 2005). By looking at these dimensions and their interrelations, it is possible to understand how the governance structure shapes the bioenergy policy process and local, sustainable development. Moreover, the comparison will use the system archetypes[5] revealed in the within-case analysis to identify the governance structure that stands behind the processes of bioenergy development mapped in the feedback loops. Behind each loop, there is a combination of rules, power relations, and actors' perception/understandings that shape the governance structure and processes of bioenergy development. For instance,in

[5]That is, simplified explanation of complex dynamics unfolding within the bioenergy system (Cavicchi, 2018).

Figure 8, we could say that there are international and national policies (i.e., rules of the game) that triggered and shaped the diffusion of bioheat in Hedmark (e.g., policy intervention and climate change goals). We can also see that the local actors' perceptions of the benefits of bioheat adoption (e.g., lower energy price option and increase in forestry income) also boosted its diffusion (loop B1). Power relations can be detected in the connection between hydropower and bioheat value chains and in the unintended consequences that link to the forestry income (e.g., conflicts of interest between forest owners). In the within-case analysis, I described both BESs by using the "fixes that backfire" archetype (Senge, 1990; Figure 3). A fix that backfires shows how an intervention to solve a problem worsens the initial conditions over time (see Cavicchi, 2018; Senge, 1990). In Senge's (2010) words "the central theme of this archetype is that almost any decision carries long-term and short-term consequences, and the two are often diametrically opposed" (p. 126). In this archetype, there is usually a problem symptom that needs to be fixed, but the solution to it makes it worse (Senge et al., 2010). "The unintended consequences of the fix (the vicious circle of the reinforcing loop) actually worsen the performance or condition which we are attempting to correct" (p. 126).

Both case studies tend to slip into the "limits to growth" dynamics (Figure 4). "Limits to growth" occurs when the reinforcing processes are offset by balancing processes that hinder the development potential of the system. Eventually, the successful intervention to boost growth pushes back, and the system resists any further improvement (Senge, 1990). This archetype "helps us to see the balance between these elements over time. It particularly helps us to come to terms with how, by pushing hard to overcome the constraints on our lives, we make the effects of those constraints even worse than they otherwise would be" (Senge, 1990, p. 130).

On top of these two archetypes, I used the generic problem and solution archetype developed by Wolstenholme (2003) to understand the link between actions and structural/behavioral constraints (i.e., constraints caused by institutional conditions and actors' actions; Figure 5).

The problem archetype shows that the intended consequences of initial actions may trigger a reaction from other actors within or outside the same sector or organization that sees this as an unintended (or unexpected) consequence. In this archetype, there is often a delay before the unintended consequences arise. For some reasons, often perceptive or structural reasons, those who have initiated the action cannot see the troubles caused by the unintended consequences. The solution archetype is about finding a fix to the problem that is in line with both the delay and the constraint.

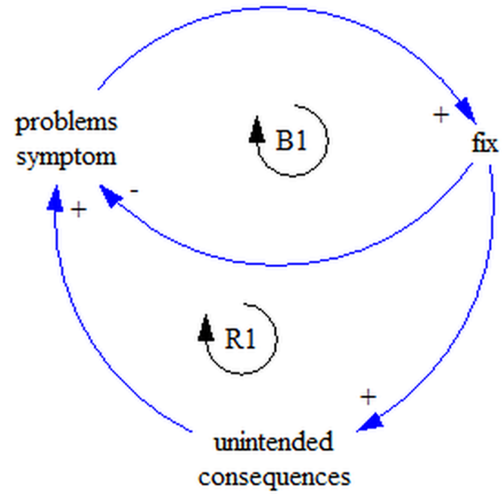

FIGURE 3 Fixes that backfire archetype—adjusted from Braun (2002, p. 14; originally fixes that fail) [Colour figure can be viewed at wileyonlinelibrary.com]

The archetype in Figure 6 (based on Wolstenholme, 2003, Figure 2) shows the "underachievement" situation. In the case studies, this underachievement archetype shows that the outcomes of the bioenergy policy (policy action/intervention) trigger a reaction from some of the actors involved in the BES, thus hitting on the constraints of the system (e.g., infrastructural constraints, biomass constraints, and social constraints). This dynamic generates a delay or underachievement of the intended outcomes over time. The solution loop in this type of archetype is about trying to build on the policy action/intervention to minimize the reactions, thus unblocking the resource constraints. This kind of underachievement archetype can both help to devise a suitable solution and analyse whether the implemented solution is mitigating the effects of the former action/intervention or otherwise reinforcing the resource constraints (Wolstenholme, 2003, pp. 12–14).

The polarity of the loops (i.e., balancing and reinforcing loops) and changes to this due to new interventions show how governance influences local, sustainable development. The feedback processes in the archetypes are the result on my interpretations of the informants' interviews (the details on these methods and the data can be found in the papers Cavicchi, 2016, and Cavicchi, 2018, to carry out the causal loop diagram analysis) but are cross-checked and matched with (a) public documents data (among others, Comitati, 2011; European Parliament and the Council, 2009; Fylkesmannen/Fylkeskommune, 2012;

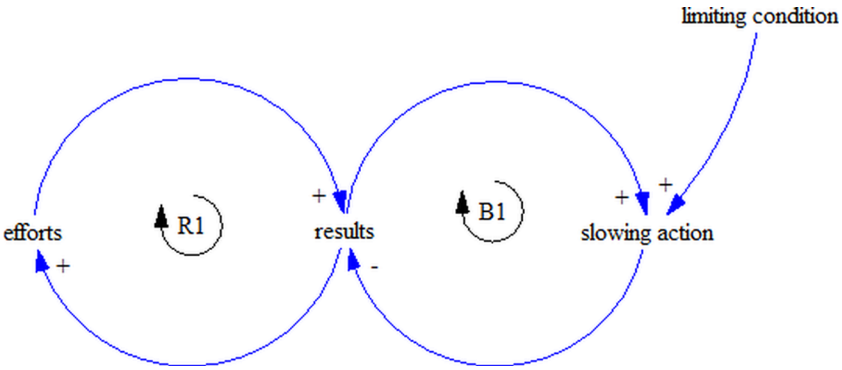

FIGURE 4 Limits to growth archetype—adjusted from Braun (2002, p. 2) [Colour figure can be viewed at wileyonlinelibrary.com]

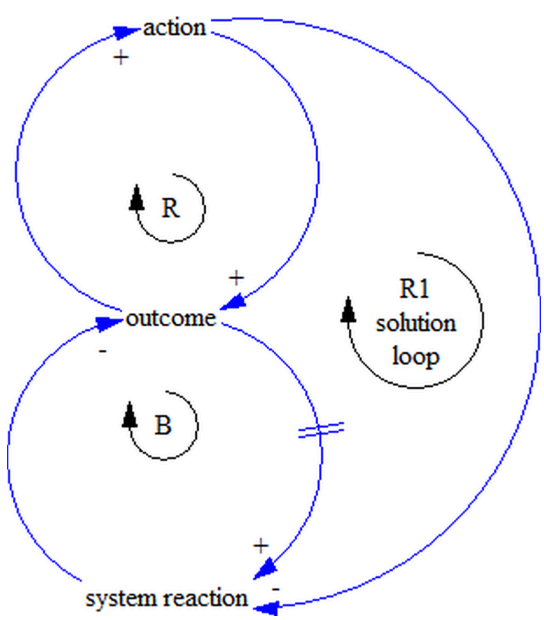

FIGURE 5 Generic problem–solution archetype—adjusted from Wolstenholme (2003) [Colour figure can be viewed at wileyonlinelibrary.com]

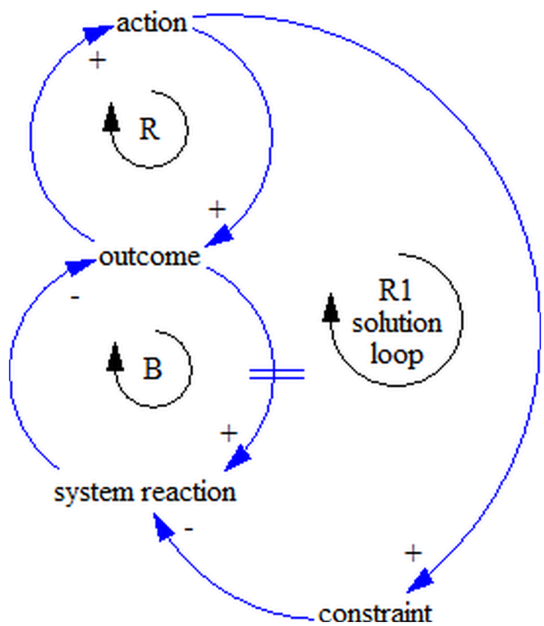

FIGURE 6 Solution to underachievement archetype (based on Wolstenholme, 2003, Figure 2) [Colour figure can be viewed at wileyonlinelibrary.com]

Giunta Regionale, 2011a, 2011b, 2012; Sandberg, 2013; Ministero dello Sviluppo Economico, 2010a; OED, 2008, 2013), (b) statistical databases (Fylkeskommune, 2014; Fylkesmannen, 2015; Gestore Servizi Energetici, 2013; SSB, 2015b; SSB, 2015h; SSB, 2015e; ISTAT, 2012; Piccini & Valentini, 2013), and (c) key literature on the case studies (Carrosio, 2013b; Cavicchi et al., 2014; Fabbri, 2013; Lindstad, 2002; Piccinini et al., 2008; Piccinini, 2013; Piccinini, 2012; Scarlat, Dallemand, Skjelhaugen, Asplund, & Nesheim, 2011; Trømborg, Havskjold, Lislebø, & Rørstad, 2011; Albrecht, 2014). The informants included foresters and farmers, forest owners and farmers' associations, local and regional public authorities, bioenergy businesses, local committees, sectorial organizations (e.g., Italian biogas organization), and experts in the field of bioenergy (e.g., researchers and professors).

4 | RESULTS

In the next sections, I will compare the governance structure on the basis of the archetypes analysis and identify the patterns of behavior that explain how governance impacts on the social and environmental sustainability of bioenergy development (Table 1).

4.1 | Archetypes analysis

In the first stages of BES development, both regional cases of bioenergy development can be described as the fixes that backfire pattern (Cavicchi, 2016, 2018). In both cases, national politicians introduced a fix (i.e., bioenergy production) via public policy and financial incentives to address the crisis of the primary sectors and related industries

TABLE 1 Comparative table

Policy feedback development	Hedmark	Emilia Romagna
First stage: Fixes that backfire	Outcomes of bioenergy policy trigger reactions in some BES actors and conflicts	Outcomes of bioenergy policy trigger reactions in some BES actors and conflicts
Second stage: Problem–solution underachievement	Removal of the bioenergy scheme for biomass value chain development	Adjustment of the feed-in tariff scheme
	Introduction of the bioeconomy strategy	Introduction of the biomethane regulatory framework
		Introduction of regional environmental regulations
Third stage: Limits to growth	Actors lose confidence in bioenergy and bioeconomy policy stability	BES hits the limits of infrastructural constraints of bioheat supply (plants too distant from buildings); rural inhabitants' lack of confidence in the BES and undelivered benefits
	BES hits the infrastructural limits of bioheat demand	

(agriculture–sugar industry in Emilia Romagna; forestry, pulp and paper, sawmills in Hedmark). Over time, the fix worsened the initial conditions (or at least did not improve them) and led to unexpected consequences. In the second stage, the policy interventions to fix the reactions to the outcomes of bioenergy development have led to different results in the third stage. In Hedmark, the BES tends to evolve into the limits to growth dynamics (Cavicchi, 2016, 2018). This consideration is not only based on my previous studies (Cavicchi, 2016, 2018) but also confirmed by the comparative analysis. The infrastructural conditions (i.e., limited use of waterborne system vs. electric heating) and the complete removal of the woodchips scheme (vs. adjustment of the policy incentive to changing conditions) have sharply limited the further development of the BES and progress in the bioeconomy transition. Emilia Romagna shows rather different dynamics because the government has been able to mitigate the effects of resource constraints or limiting factors, that is, social opposition triggered by local economic and environmental consequences and undelivered benefits, by adjusting the feed-in tariff scheme and introducing the biomethane regulatory framework. However, the infrastructural constraints of the supply of bioheat (biogas plants too distant from buildings), the rural inhabitants' lack of confidence in the BES, and the undelivered local benefits might challenge the sustainable evolution of the sector in the case study.

In the two case study regions, following the arising social opposition at the local level and contextual changes (e.g., decrease in hydropower price), national politicians modified or removed the policy incentives, thus influencing the actors' expectations on the benefits of bioenergy development. However, whereas in Emilia Romagna the unintended consequences seem to have opened the system to new, though timid, opportunities (e.g., biomethane; smaller biogas plants based on byproducts and waste biomass) and gradually generated more and more benefits, despite the power issues, in Hedmark, the system seems to remain trapped in old power issues and contextual features such as the energy system path dependency (hydropower). These feedback processes see the interrelations of old and new governance dimensions.

In Emilia Romagna (Figure 7), the bioenergy discourse was built around three core issues: the phasing out of the sugar industry and sugar beet production (consequence of the 2004 EU Common Agricultural Policy reform), dependence on natural gas import, and environmental pollution, especially in the agriculture and livestock in connection with EU climate and energy targets. The actors that framed this initial bioenergy discourse were mainly the sugar beet farmers and farmers' unions, sugar industry, regional and national politicians particularly concerned with the decline of the sugar industry and agriculture and dependence of fossil fuels, energy companies and regional multi-utilities (HERA and IREN[6]), and the Centre for Animal Research. Some of them (e.g., farmers, farmers' unions, sugar industry, and Centre for Animal Research) developed expectations in that sugar factories could be transformed in biorefineries, and the sugar beet land converted into energy crops land (see Cavicchi, 2016; Cavicchi & Ely, 2016). Regional politicians who were strongly connected to the sugar industry by economic and political interests supported this view. These dominant actors controlled essential natural (e.g., land), infrastructural (energy grid), knowledge (e.g., on

[6]HERA and IREN control most of the regional natural gas transmission grid. HERA is the biggest producer of bioenergy in the country (AEEG, 2013a,d).

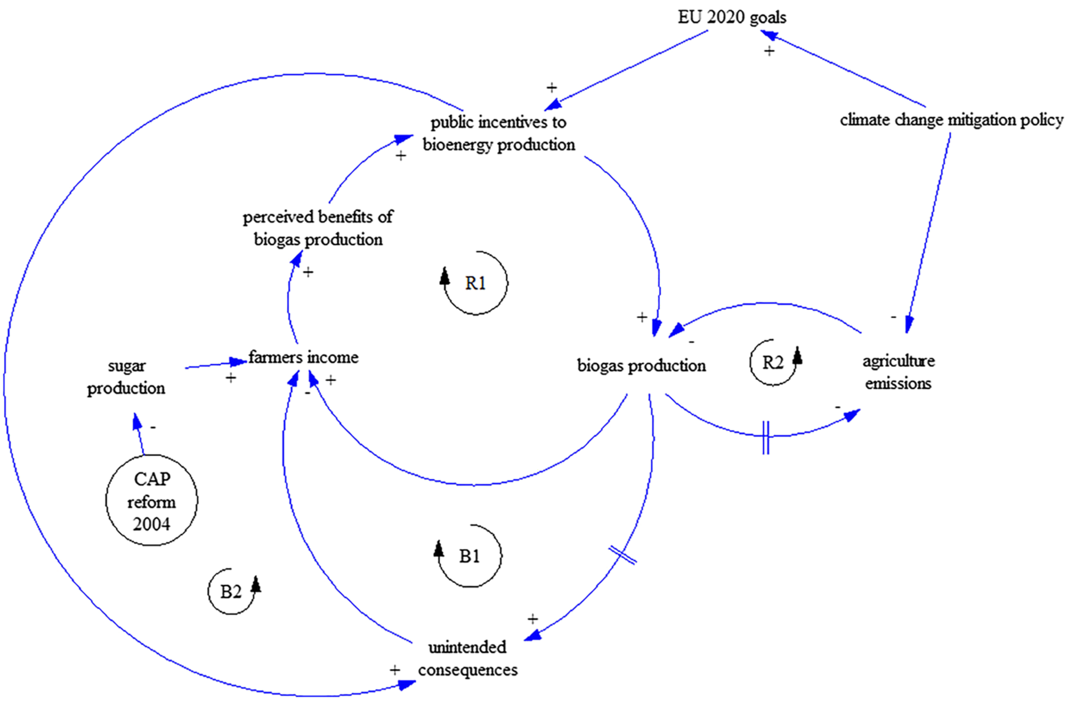

FIGURE 7 Fixes that backfire in Emilia Romagna. CAP, Common Agricultural Policy [Colour figure can be viewed at wileyonlinelibrary.com]

biomass and biological processes), and bargaining (e.g., votes) resources.

Additionally, the national government believed that bioenergy production could reduce the dependence on natural gas for energy production and contribute to reaching the EU renewable energy and climate change goals (see loops R1 and R2; Ministero dello Sviluppo Economico, 2010b). Electricity supply was then targeted as the easiest way to fulfil the obligations (e.g., Direzione Generale Agricoltura E.R., 2007; Ministero dello Sviluppo Economico, 2010a). Therefore, at the end of 2008, the government adopted an incentive scheme to boost bioenergy production, namely, a feed-in tariff scheme that diversified the tariff per type of technology rather than per type of biomass or priority to small-size plants (i.e., energy production capacity; Gestore Servizi Energetici (GSE), 2010). It also introduced a tax exemption on farm-based biogas production (i.e., 51% of the biomass must come from the farm's activities for the farmer-biogas producer to register as a farmer; see R1). On top of this, existent rules and ecosystem conditions influenced the governance of the BES and determined the dominant and excluded actors and power relations between them[7] (e.g., municipalities have residual power concerning renewable energy land planning; Consiglio Regionale, 2004, Clauses 2–4). These institutional conditions, coupled with the feed-in tariff and tax exemption boosted a land acquisition process that involved not only farmers but also many "nonfarmers" (e.g., manufacturing or food industry entrepreneurs). The latter bought and rented farmland from old farmers to invest in biogas production and access the financial subsidies. As a result, within 2009–2012, the number of biogas plants in the region increased almost sixfold (from 29 plants in 2008 to 172 in 2012). Third, biogas production and electricity supply built upon the natural gas-based energy system. The latter is rather centralized and prioritizes large-scale transmission companies. This structure and the interests of dominant energy actors limited the use of biogas to the electricity supply. Lastly, the ecosystem conditions emphasized the need to reduce emissions in agriculture and livestock, transports, and industry. However, biogas production only tackles the problem of pollutants in agriculture and livestock, whereas it does not contribute to reducing industrial and transportation emissions. Moreover, biodiversity and soil quality had a minor role in the BES pathway development.

[7]Second, land ownership and acquisition rights are mostly subjected to market dynamics. However, there are tax privileges for family members who inherit and/or cohabit with the farm owner (Tonalini, 2016). The Stability Law n. 208 (2015) established the tax that buyers must pay on the acquisition, registration, and mortgage of farmland. Taxes are higher for those who are not farmers and special tax exemptions apply to family members (Presidente della Repubblica, 2015; Tonalini, 2016).

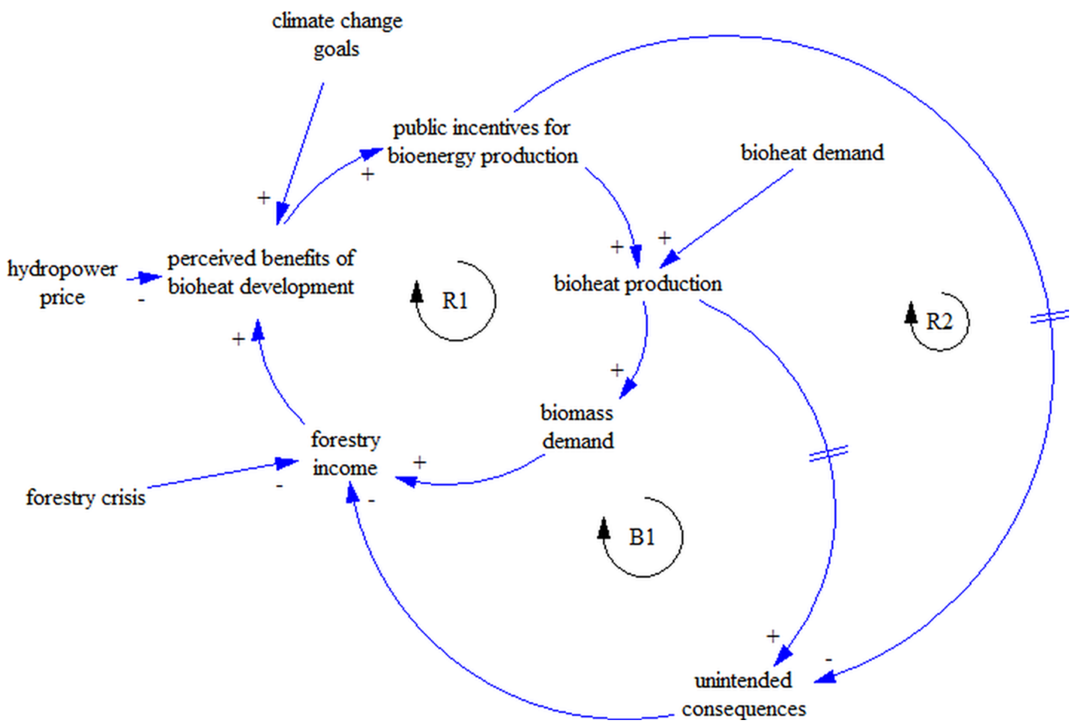

FIGURE 8 Fixes that backfire in Hedmark [Colour figure can be viewed at wileyonlinelibrary.com]

As a short-term reaction to this "exclusive" system that prioritized individual investments over cooperatives, large farms over small farms, and energy crops over farming residues (B1), the BES governance structure was put under pressure by social opposition, financial losses, and impacts on biodiversity and soil quality, local warming, and CO_2 emissions. These unintended consequences uncovered organizational, infrastructural, and ecosystem issues that jeopardized the ability of the system to deliver sustainability. First, conflicts between small and large farmers and the rural-industrial interests' cleavage intensified. Second, trust among actors and particularly between local inhabitants, politicians, and businessmen was undermined. Third, the BES supplies electricity to a centralized grid, thus adapting to the dominant energy system based on natural gas, rather than providing alternative and locally decentralized energy options. Fourth, biogas production unveiled the vested interests of the dominant energy system. Notably, the companies that supply natural gas and control the natural gas grid tend to determine the alternative uses of biogas (e.g., in transports; as a source of biomethane and heat) and prevent biogas supply decentralization. Lastly, the effects on the local ecosystem were overlooked. Biogas production triggered ecosystem dynamics such as local warming (heat dispersion from the plants); biodiversity and soil quality loss (e.g., leachate flowing from the plants into irrigation ditches); bad smells, landscape damage, local traffic, and particulate emissions that are stressors for an already fragile regional ecosystem (B1). Social opposition arose from these issues, but although it seemed to be a limiting factor, in the medium term, it proved to be a force of change (Cavicchi, 2016; Cavicchi & Ely, 2016). Regional policymakers were forced to invest more efforts to protect the environment, thus introducing stricter and more formal environmental regulations.

Moreover, at the national level, policymakers introduced the biomethane strategy, thus triggering a diversification of the BES. Lastly, instead of removing the feed-in tariff scheme, they modified it to better adapt to the local conditions, for example, support to small-scale and waste-based bioenergy projects. Although there have been only a few more investments in biogas since then, the interest in biomethane has been growing.[8]

In Hedmark, actors who had similar affiliations to those of Emilia Romagna shaped the bioenergy discourse (Figure 8). The bioenergy discourse unfolded around three core points: the ongoing decline of forestry and related industries (pulp and paper, and sawmills); increasing hydropower price and need for cheaper energy options; and EU renewable energy and environmental and climate obligations. Large forest owners and forest

[8] http://www.rinnovabili.it/energia/biomassa/impianti-di-biometano-italia/; https://www.lastampa.it/2019/01/28/scienza/biometano-a-che-punto-siamo-in-italia-Q8nuQbLje9x8jXlw3HYi9K/pagina.html; http://www.rinnovabili.it/energia/biometano-in-italia/

associations, rural industries, local and national politicians, and energy companies expected bioenergy to provide a new market to forest products, cheaper energy to rural industries, benefit the rural communities and the environment more in general. These actors controlled key resources such as natural (e.g., wood), knowledge, technical, financial, and social (e.g., social networks) resources. The Bioenergy Strategy is nationally handled by the Ministry of Oil and Energy (OED, 2008). The strategy set up the goals by 2020[9] and prioritized forest-based biomass over other products to fulfil the target (loop B1; Cavicchi, 2018; Albrecht, 2014).

The Ministry of Food and Agriculture (via Innovation Norway and Norwegian Agriculture Agency) and the Ministry of Climate and the Environment (via ENOVA Agency) are responsible for the incentive schemes, whereas the County Department of Agriculture is responsible for bioenergy policy implementation, and the municipalities are in charge of land planning (e.g., where to locate the plant and pipelines). The three ministries involved in bioenergy development required different incentive schemes. For instance, in 2008, the government introduced an incentive scheme to boost woodchips supply (the scheme ran for three years 2009–2012). Additionally, the public sector was required to phase out fossil fuels by 2018 to reduce CO_2 emissions. Meantime, ENOVA's grants system[10] to large-scale bioenergy production in place since 2001 and the Innovation Norway's grants system[11] to small-scale forest-based bioenergy production started in 2008 backed up the woodchips scheme. This bundle of rules and incentives boosted forest-based bioenergy production. Currently, in Hedmark, there are approximately 260 farm-based plants and approximately 30 district heating and local bioheat plants (Fylkesmannen, 2015; Fylkesmannen & Fylkeskommune, 2008). Existent institutions shaped the governance structure on the BES, which compared to Emilia Romagna, is more inclusive and based on participatory processes. First of all, land planning at the local level generally involves local inhabitants via public hearings to discuss the location of the plant and pipelines. Second, the BES developed around bioheat production and supply, thus linking the bioenergy companies with local consumers, yet limited by the predominance of the existing hydropower infrastructure. Third, the ecosystem conditions showed a quite good system in Hedmark, although there is a need for better forest management (e.g., many forest resources are not harvested every year), which is expected to contribute to biodiversity and carbon capture capacity.

Bioenergy and biomass supply go in this direction. Lastly, the laws regulating forest property rights and acquisition rights influenced the biomass value chain development. In Norway, the forest property rights follow inheritance criteria (see Concession Act, Allodial Act, and Land Act). The fundamental principle is that non-industrial private properties (the majority) may not be acquired without a decision of the King. Currently, a responsibility delegated to municipalities (Concession Act, Clause 2). Besides, unless the ministry decides otherwise, agriculture and forestland cannot be divided into new properties (Land Act).

Additionally, the blood inheritance right forbids selling agriculture estates to external parties unless all the members with allodial rights have renounced the ownership. Lastly, there are price control and tax mechanisms for selling family-owned forest estates outside the family (see Follo et al., 2015). On the one hand, these rules might exacerbate ownership fragmentation, ownership type and size (e.g., small and large, and the commons—almenningen), and dispersion of critical activities (e.g., biomass extraction, processing, and transport). On the other hand, it discourages large businesses and multinational companies to embark in a forest-resources rush in rural areas (Cavicchi, 2018; Follo et al., 2015; Lindstad, 2002; Taylor and Follo, 2011).

The BES thus evolved as a rather inclusive system with proper learning mechanisms and resources sharing, although locked in in the dominant energy and forest systems. These mechanisms were expected to reduce costs for bioheat producers and forest owners and prompt the demand for bioheat (R1). The structure of the BES did not cause shocks to its governance stability, but, instead, it intensified the stressors. It exposed the weaknesses of forestry and related industries, the infrastructural and financial limitations of bioheat production itself, and the ecosystem dynamics linked to increased biomass extraction. First, the differences and contrasts between small and large forest owners intensified. Large forest owners control more key resources (e.g., knowledge, financial, and technological resources) and infrastructures and have stronger ties with the forest industries both inland and abroad (e.g., Sweden). Small forest owners are usually in the opposite situation and, for instance, tend to leave their forest property unused (see also SSB, 2016). The bargaining power of large and small forest owners is also unbalanced. Notably, large forest owners have more ability and possibility to influence decision makers and

[9] 28.5 TWh by 2020 (starting from 14.5 TWh in 2008).

[10] ENOVA supports big investments such as district heating facilities and <10-MW bioenergy plants; in addition, the agency also supports innovative projects concerning climate change technology.

[11] Innovation Norway provides financial help to small-size and farm-based bioenergy plants. Other important regulatory instruments are the target to phase out fossil fuels consumption from public buildings and the local climate and energy plan.

economic interests that seem to inhibit cooperation and resource sharing beyond the community borders (B1; Cavicchi, 2018). For instance, big bioheat companies (e.g., Eidsiva) prefer to rely on large forest owners' biomass supply. They claim that large forest owners secure a more stable biomass supply compared with small forest owners whose activity is often subjected to weather conditions throughout the year (e.g., cold winters) and other factors (e.g., technological equipment). In turn, large forest owners consider big bioheat companies to assure a steady demand for biomass and profit in the long term (Finstad & (AT Skog og AT Biovarme), 2015; Cavicchi, 2018) Second, the development of bioheat showed that it is challenging to adopt alternative energy sources in a hydropower-based energy system. The waterborne infrastructure in the country is minimal, and bioheat is bound to the hydropower price. Namely, bioheat cannot be sold at a higher price than hydropower without becoming uncompetitive. Third and lastly, due to the high amount of nonextracted forest resources, the ecosystem dynamics related to bioenergy have been partially neglected. However, the increasing use of forest machinery and tracks for biomass extraction risks to endanger forest biodiversity and soil quality and CO_2 emissions.

If we recall the problem–solution archetype (Figure 5) and apply it to the final stages of the bioenergy momentum in the case studies, we can see that the responses of the actors in both BESs have been dissimilar. In Emilia Romagna, the actors excluded from the BES governance (i.e., local inhabitants and environmental organizations such as Legambiente) raised issues such as the lack of benefits provision to local agriculture and rural areas and better environmental regulations (e.g., small-scale bioenergy production, bioheat supply, biomethane production, and use biomass from agriculture and household waste). They submitted a request for a moratorium to the regional government to ask for a suspension of the concessions to build new plants (Comitati, Unione dei, 2011). These actors were able to mobilize alternative knowledge concerning biogas production and key votes to national and regional politicians. The fixes introduced by both national and regional decision makers, that is, environmental regulations and changes in the support schemes and the biomethane regulatory framework (Giunta Regionale, 2013; Giunta Regionale, 2011a; Ministero dello Sviluppo Economico, 2013; ENAMA, Murano, Maisano, & D'Amore, 2014), have slowed down investments in large biogas plants (B1) but opened new opportunities for small-scale, waste and agriculture by-products-based plants and biomethane. These changes have ensured the continuity of the transition and calmed down the social opposition and conflicts previously arose (B2, Figure 6).

In Hedmark, as soon as the hydropower price dropped, rural industries lost interest in bioheat supply. These unexpected events, among other things (e.g., change in government), led to the removal of the woodchips scheme in 2012. This fix caused the large forest owners to lose interest in supplying biomass to bioheat companies (R2; Cavicchi, 2018). The differences between small and large forest owners reintensified and reinforced the limits to bioheat adoption (R1, in Figure 7). The removal of the scheme enormously weakened the bioenergy momentum and may also have affected the progress of the bioeconomy transition, thus probably intensifying the unexpected consequences (R2, Figure 7). In 2016, the government adopted a bioeconomy strategy (Regjeringens, 2016), but there is no evidence of an arising bioeconomy momentum in Norway. The archetype (Figure 7) shows that these developments slowed down bioheat adoption.

5 | DISCUSSION AND CONCLUSION

This study aimed first to shed light on how the governance structure of the BES triggers multilevel feedback dynamics that affect local, sustainable development by focusing on the case of bioenergy. Second, it aimed to contribute to the policy analysis literature (particularly within the field of sustainability transitions) with a better understanding of how these feedback dynamics shape the policy process pathway, thus impacting on sustainable development. The study assumed that bioenergy policies were expected to deliver opportunities for local and rural development, mitigate the impacts of climate change, and provide a means for better land and forest management. Ultimately, bioenergy development was expected to promote the environmental and social benefits not only at the local level but also across scales (e.g., CO_2 emissions reduction). However, how the bioenergy policies are implemented and by whom (i.e., visions, values, and power relations) determined the effects on the local environment and society. On this basis, the key considerations are as follows:

1. In both BESs, power relations coupled with existent (e.g., land property rights) and new rules (e.g., policy incentives) have a significant influence on the processes of bioenergy development in terms of both the rules of the game and actors' perceptions. This has a substantial impact on local, sustainable development.

2. Social opposition (or bottom-up demands) is a driving force for opening the system to new approaches, products, and strategies, as demonstrated by the Emilia Romagna case. Small farmers and forest owners, municipalities and local inhabitants who refreshed the bioenergy discourse, led to changes in discourses and policies and altered dominant power relations. In Hedmark, the BES has been more inclusive, but, ultimately, there has not been a shift in power relations and a change in policies that shows a pathway redirection.
3. The analysis of the interdependence between social–environmental elements emphasizes the implications of overlapping policies and sectors in the sustainability transitions processes. The way local inhabitants perceive the environment around them and its use determine the acceptance or refusal of new natural resources-based production activities. This proves the importance of analytically looking at the feedback relations between the ecosystem and the social system in both research and policy analysis.
4. Feedback dynamics are a crucial element to be addressed in sustainability transitions policy analysis. Feedback acts at and across different levels. Sustainability transition policies are overlapping; that is, they touch upon and link different sectors (e.g., primary sectors, natural resources management, waste management, and energy), thus increasing the complexity of actors' interrelations, multiple understandings, and visions of real-world events, power relations, and institutional structures involved. Analytically, a better understanding of feedback and its impacts on the policy process (from implementation to policy design change passing through the reactions to the outcomes of implementation processes) is necessary to improve local, sustainable development.
5. Using archetypes and system dynamics supports the analysis of feedback emphasized in Point 4 above. Systems thinking (as including both archetypes and system dynamics) assists not only with the analysis of feedback and implications for the policy making and local, sustainable development but also with the inclusion of "time delays" (even though just at a cognitive level). Time delays are consequences of feedback processes in that it takes time for events to show the consequences and for humans to learn about these. Using systems thinking increases the actors and policy makers' awareness of time delays, thus potentially allowing for a shift in mindset and policy design.

These final points highlight (a) increasing necessity to involve the variety of stakeholders in the early stages of policy design development. Inclusion comes with economic costs and conflicts between different visions, but it can help to build a common understanding and shared goals of sustainability transitions, for example, within the field of bioeconomy. For this to happen, it would be necessary to rely on skilled facilitators who can help to bring the different needs, values, and visions on the stage and focus (or find) the commonalities rather than the differences. Most important is to remember and accept that none will ever be fully satisfied with the decisions and their outcomes. Ultimately, it is a continuous feedback-learning process. The final points also highlight (b) a necessary change in mindset. Notably, conflicts and differences should be treated as opportunities to learn and steer change to improve existing conditions. Social opposition and conflicting interests are rooted in different cognitive abilities, social status, and so on. Communication is key to this point and should not be disregarded. Communication can be supported again via the involvement of experts that, among other things, can help to convey the local knowledge up to the scale to regional and national policy makers. The third is (c) urgency to account for time delays. Time delays are a crucial feature of feedback dynamics. Thus, policy frameworks should be designed to allow for some time before they are modified or removed. Perhaps they could include monitoring phases open to yearly adjustment and phase-in/phase-out mechanisms. Such mechanisms would help first to build trust in the political and policy systems. Second, they should be designed to provide enough time for the actors to adjust to changing conditions and needs. Third, they should be designed to prevent them from falling out at the early stages, if not necessary. (d) Archetypes are useful to understand the underlying mechanisms of sustainability transitions and the link between structures, human actions, and the real world. Archetypes helped in different ways. First, their use allowed simplifying complex feedback processes, which I already analysed in other published papers. The archetypes provided a summary of the crucial system dynamics. Second, the archetype helped to look beyond the process variables to see which structural dimensions orchestrate those very same processes. The possibility to link processes and the governance structure could be a contribution to the field of governance studies and operational research. Concerning the latter, it could help to see beyond stocks and flows and discover the subtle power relations, informal rules, and dominant discourses that shape business management and decisions across hierarchical structures. (e) Learning could be boosted via policy experimentation and a polycentric and multilevel governance system. As Donella Meadows writes, "encouraging variability and experimentation and diversity means 'losing control'." Agencies and other private actors at different levels/scales should be given integrated responsibilities and autonomy to intervene but under the same general rules and scale-adapted targets. A step in this direction should be to identify cross-scale issues that require a cross-jurisdictional approach and governance scaled to impact.

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