Geoforum 82 (2017) 66–76

Contents lists available at ScienceDirect

Geoforum

journal homepage: www.elsevier.com/locate/geoforum

The politics of imaginaries and bioenergy sub-niches in the emerging Northeast U.S. bioenergy economy

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ARTICLE INFO

Keywords:
Bioenergy
Marginal land
Multi-level perspective
Object conflict
Scale
Sociotechnical imaginary

ABSTRACT

As part of a transition to lower carbon energy systems, bioenergy development is often assumed to follow a uniform pathway. Yet the design, organization, and politics of bioenergy production in specific regional contexts may be contested. This study examines contestation within an emerging perennial crop bioenergy sector in the U.S. Northeast. Synthesizing conceptual contributions from the multi-level perspective on the significance of niches and sub-niches in sustainability transitions and from science and technology studies on the material and moral implications of sociotechnical imaginaries and object conflicts, this paper analyzes the politics of bioenergy sub-niche imaginaries. It identifies two main bioenergy sub-niches centered on (1) regional production and (2) community energy. Examining proposed and current production of perennial energy crops on marginal land, the study draws on 42 semi-structured interviews with bioenergy actors (e.g., scientists, industry representatives, policymakers, farmers/landowners) and secondary documents. The two bioenergy sub-niche imaginaries revealed political contestations around scale of operations, control and beneficiaries, and about definitions and uses of marginal land relative to livelihoods and community. This study highlights the potency of rival imaginaries *within* a developing sociotechnical niche and implications for sustainability transitions. Tracing the contours and emphases of, as well as conflicts between, bioenergy sub-niche imaginaries can clarify which pathways for transition to a lower carbon energy future could garner political and public support. The paper concludes by considering how disagreements between sub-niche actors could lead to productive mutual learning and the possibility of forging solutions contributing to more robust and equitable sustainability transitions.

1. Introduction

Transition to a less carbon intensive, renewable energy system is paramount for achieving social and environmental sustainability goals. Geography and science and technology studies (STS) scholars have called attention to the role that sociotechnical imaginaries, or collective visions and accompanying policy frameworks for achieving a “good society” via technology development (Calvert, 2015; Jasanoff and Kim, 2015; Smith and Tidwell, 2016), play in shaping sustainability transitions. In the United States, powerful actors, including national-level industry groups and policy-makers, envision bioenergy development as one important renewable resource pathway towards achieving a low carbon energy system. The national bioenergy sociotechnical imaginary rests on using biomass resources to reduce fossil fuel dependence, revitalize rural economies, ensure energy security, mitigate climate change, and provide environmental services such as water quality improvement (Eaton et al., 2014; Lehrer, 2010; Selfa et al., 2015; Tilman et al., 2006).

In the Northeast United States, developing a bioenergy economy based on perennial energy crops (e.g., switchgrass or short-rotation woody crops) grown on marginal land is seen by many actors as central for enacting this imaginary (e.g., NEWBio.psu.edu; Stoof et al., 2015; VSJF, 2014). At the same time, other actors in the region have advocated for and are pursuing alternative visions for bioenergy development, visions that prioritize more “localist” approaches focused on reclaiming local control of economies and opposing their corporate

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http://dx.doi.org/10.1016/j.geoforum.2017.03.022
Received 28 March 2016; Received in revised form 13 March 2017; Accepted 22 March 2017
0016-7185/

colonization (Hess, 2009, 7; Hess, 2010). Rather than responding to national energy needs, these visions stress maintaining smaller-scale, distributed and flexible production on the land as the basis for a more equitable economic system.

Divergent options in bioenergy production systems and their accompanying sociotechnical imaginaries raise important questions not only about how bioenergy crops should be grown, harvested, processed, and used (van der Horst and Evans, 2010), but also about which bioenergy development model will provide the greatest social, environmental, and economic benefits and for whom. Even as a national sociotechnical imaginary for bioenergy has solidified, different actors and interests in the Northeast U.S. disagree about what are desirable and appropriate forms of bioenergy development, and what a future "good society" made possible via bioenergy technologies should look like. However, the contours of these contested visions and their material and discursive implications have received little scholarly attention.

In this paper, we examine ongoing political struggles—what we call *a politics of imaginaries*—unfolding between actors promoting different forms of bioenergy development in the Northeast as means to achieve rival imagined futures. We contend that analysis of these visions is important as whose imaginary 'wins'—that is, becomes manifest in technology infrastructure, policy, and standards—has implications for both politics of discourse and values and the distribution of material goods and bads (e.g. financial resources and environmental burdens) (Busch, 2011; Latour, 1991; Sclove, 1995).

To develop our analytical approach, we draw from and synthesize three bodies of social science literature on technology development. First, we position bioenergy development in the Northeast in terms of what the multilevel perspective (MLP) on sociotechnical transitions literature (Geels, 2002, 2005, 2010) terms "niche" technology development, referring to emerging, novel technologies that have yet to be incorporated into the broader sociotechnical system. Linking the MLP framework to Jasanoff and Kim's (2009, 2015) notion of sociotechnical imaginaries, we then highlight how niche actors envision their respective technological projects not only in technical, but also moral terms by calling attention to how particular technological choices would produce either better or worse future societies and for whom. Our research uncovers the contested dimensions of actors' visions for a future good society within the same bioenergy niche. To analyze how the material and moral dimensions of these actors' projects are interwoven, we draw on Hess' (2005, 2007) notion of "object conflicts," or definitional struggles between actors pursuing different ends within the same technological niche. Synthesizing facets of these three literatures provides the foundation for our research questions: how is bioenergy development in the Northeast U.S. envisioned and for what sociotechnical imaginary, and by whom? What do these sociotechnical imaginaries entail? And how are they contested?

Our findings show that actors constructed their bioenergy priorities and activities according to their vision of how bioenergy can be used to secure a better future society, while simultaneously challenging the visions of their rivals. Advocates of the dominant imaginary for large-scale bioenergy development, what we call the regional production model, envisioned a future where land and landowner practices are shifted toward dedicated energy crop production supplying centralized energy systems to provide environmental and economic benefits resonating with national and regional-scale policy aims for a bioenergy economy. Alternatively, what we call the community energy model imagined local-scale bioenergy systems that fit closely with existing land use practices and prioritize economic benefits to the local community through direct marketing and use of bioenergy products to increase local producers' autonomy and control.

We argue these competing visions shape bioenergy niche development in two ways. First, some advocates of the dominant regional production imaginary discredited the economic and environmental sustainability of smaller-scale systems, thereby diminishing the potential of alternatives to large-scale, centralized systems in the eyes of policy-makers and the public. Concurrently, some farmers, landowners, entrepreneurs, and others contested this dominant imaginary by appealing to an alternative vision of small-scale, decentralized bioenergy production as a means of prioritizing community benefits and reorganizing economies to enact localist imaginaries.

In the next section, we review and synthesize literatures on (1) the MLP, (2) sociotechnical imaginaries, and (3) object conflicts in the field of energy technologies to develop our *politics of imaginaries* conceptual framework. We also discuss the significance of scaling and marginal land in energy transitions to contextualize key thematic tensions in this research. We then introduce the study region, describe the different forms of bioenergy production present, and highlight the activities of the New York Grass Cooperative (NYGC) to demonstrate the significance of bioenergy sub-niches in the Northeast. Methods, results, and discussion follow. Our intent is not to suggest that either the regional production or community energy model is better than the other. Rather, we conclude by arguing that the tensions between different bioenergy imaginaries point toward possibilities for imagining multiple bioenergy paths for obtaining better futures.

2. Literature review

2.1. Multilevel perspective on sociotechnical transitions

The MLP theorizes how sociotechnical systems evolve and transition toward more sustainable forms (Geels, 2002, 2005, 2010). In this framework, transitions emerge through interactions across three levels: landscapes, regimes, and niches. The landscape includes cultural norms and values; political coalitions and legal or regulatory changes; and economic, social, and environmental changes that provide a macro-level structuring context within which sociotechnical transitions occur. Regimes are meso-level forms of governance and sociotechnical practice that structure and stabilize existing sociotechnical systems and determine how technologies are developed and used. Finally, niches are experimental spaces where innovations can be developed and trialed outside of the normal selection pressures exerted by the mainstream sociotechnical system (Kemp et al., 1998). Niche development is pursued by small networks of actors who support novel sociotechnical practices based on their imaginaries of what these can achieve to better their communities and society (Marsden, 2013; Pesch, 2015).

2.2. Critiques of the multilevel perspective

Much scholarship within the MLP tradition has analyzed already completed transitions, while neglecting emerging transitions. Further, this work has generally focused on the temporal and technical dimensions of transitions, while ignoring their place-based dimensions and the social actors shaping transition outcomes (Bridge et al., 2013; Karanikolas et al., 2015). Recent scholarship has critiqued the MLP for paying inadequate attention to place, space, and scale (Bridge et al., 2013; Hansen and Coenen, 2015; Hodson and Marvin, 2013), and for emphasizing elite actors and technologies at the expense of local knowledge and context-specific social process and political dynamics (Lawhon and Murphy, 2012; Lawhon, 2012). Of particular importance for this study are questions of niche actors' competing visions of appropriate scale and land use for achieving their bioenergy imaginary, which we highlight by developing the bioenergy sub-niche concept.

2.3. Bioenergy sub-niches

MLP-focused research has largely treated niches as homogenous spaces where actors share attitudes, values, and sociotechnical practices in working towards a common goal (Gibbs and O'Neill, 2014, 2015). However, heterogeneous sociotechnical configurations with contrasting visions and practices of sustainability often exist within a single niche

(Gibbs and O'Neill, 2014, 2015; Lawhon, 2012; Smith, 2006). It therefore becomes important to understand how sociotechnical imaginaries drawn on by different niche actors can complement, but also contradict one another. As Murphy (2015) suggests, the political dynamics present in transition processes "can be understood as a form of relational place-making and framing," with competing visions for a sustainable future vying for control over "the direction, scope, and pace of its development" (p. 74). To account for this heterogeneity, Gibbs and O'Neill (2015) argue that niches comprised of several experimental clusters are better understood as a "series of nested sub-niches," rather than one niche representing a uniform alternative to the regime. Below we develop a conceptual framework for analyzing competing sociotechnical imaginaries across bioenergy sub-niches drawing on literatures from sociotechnical imaginaries, social movements, and contestation centered on technological innovations.

2.4. Politics of imaginaries in niche development

As STS scholars argue, technoscientific projects both explicitly and implicitly embody the moral and political choices of their promoters. The sociotechnical imaginaries concept has built on this tradition by highlighting the visions for "good and attainable" futures that accompany technology development agendas, and how they help legitimize the material, social, and environmental costs of their development and accompanying policy frameworks (Jasanoff and Kim, 2015; Pesch, 2015; Tidwell and Smith, 2015). This literature initially focused on the dominant imaginaries of powerful actors that resonate at national levels (Jasanoff and Kim, 2009). However, recent research documents the heterogeneity of imaginaries for the same technology or industry (Smith and Tidwell, 2016), as well as challenges to dominant imaginaries and the promotion of alternatives at local and regional levels (Hess, 2015). Examining the contending imaginaries of sub-niche actors in sociotechnical transitions can reveal whose visions dominate and why, and how these dominant visions are challenged by actors within the same niche (Bouzarovski and Bassin, 2011; Hess, 2015; Levidow et al., 2013; Levidow and Papaioannou, 2013; Ponte and Birch, 2014). Eaton et al.'s (2014) study of bioenergy development in the upper-Midwest U.S. showed how community residents where bioenergy facilities were proposed drew on differing understandings of the region's environmental past to construct contrasting imaginaries that either adopted or contested the national bioenergy imaginary. Likewise, in a comparative analysis of two energy-producing communities in the American West, Smith and Tidwell (2016, 355) reported workers' experiences producing energy "prompts these residents to reframe the dominant, consumption-oriented vision of energy in a good society to include quality blue-collar labor." As these examples suggest, the sociotechnical imaginaries literature has emphasized the moral dimensions of technology development, and how visions for what a good future should look like are linked with material features of technology systems. However, how different sub-niche actors envision the good society that an energy transition can enable and how they enact their vision through material practice are both undertheorized and lack empirical examination. This intertwining of the moral and material aspects of bioenergy technologies—how different possible arrangements and outcomes of bioenergy development are envisioned and contested in moral terms—merits more analytical attention.

We provide this by bridging the MLP and sociotechnical imaginaries literatures with research on the dynamics of contestation between actors with a shared interest in a particular technology or industry (Hess, 2005). Joining STS and social movements studies, Hess (2007) drew on case studies of renewable energy technologies to examine how citizens, social movements, and industry actors mobilized to contest or influence technology policies, as well as the material aspects of technologies, such as design and selection. Contestation can take several forms, including opposition movements seeking to impede specific technologies, but also movements that generally support a technology but advocate for specific changes in design, scale, efficiency, or other features. STS research has argued that technology selection and adoption form a jointly material and symbolic process because political values are embedded within technology design—whether or not planners, engineers, or others do so deliberately (Winner, 1986). Technology development is therefore a political process because design choices and selection affect users, groups, and communities differently (Callon et al., 2011; Sclove, 1995). Actors challenging technology design, selection, or implementation must then contest both the symbolic (e.g., values, imaginaries) and material features of those technologies. Hess' (2005, 518) concept of "object conflicts" extended this earlier STS literature by analyzing how mobilized publics target changes to design, selection, and other technology features, and how these goals are "embedded in a much more extensive agenda that is often linked to a social movement." Our politics of imaginaries approach melds the MLP and sociotechnical imaginaries literatures and the object conflicts concept to examine how bioenergy sub-niche actors interweave morality and material features of bioenergy technologies in voicing and contesting imaginaries of a future bioeconomy. In particular, we show how contestations in the Northeast's bioenergy sub-niche unfold around competing imaginaries for the proper scaling of bioenergy development and the best use of land and crops for producing energy.

2.5. Scale and marginal land in the emerging bioenergy economy

In the energy transitions literature, the term scale has referred to the material size of applied technologies, the size of the area where they will be deployed, and the geographical reach of the political structures and economic organization that govern and organize energy systems (Bridge et al., 2013). Bridge et al. (2013) suggested studies of scale in energy transitions use the verb scaling to capture the "the emergent character of geographical scale" and highlight that the scales at which energy systems are organized and governed proceed from economic and political choices with distributive effects. Similar to other energy technologies, bioenergy can be implemented at diverse scales. For example, biomass can be harvested from a single farm and used to heat the owner's home and outbuildings, but can also be harvested from large-scale grain operations and delivered to ethanol plants. Accordingly, the implementation of bioenergy technologies can have varied implications for reducing carbon emissions, changing landscapes, or generating environmental and community impacts (Bridge et al., 2013; van der Horst and Evans, 2010; Walker and Cass, 2007). With its relationship to visions for local versus extra-local environmental and economic benefits, scaling becomes particularly important for bioenergy sociotechnical systems, which are often at least partly embedded in existing networks and relations of agricultural production that include infrastructure, equipment, and chemical companies; creditor-debtor relationships; and farming practices that shape wages. Scaling of the emerging bioenergy economy in the Northeast therefore affects how the sociotechnical system may be both challenged and reproduced.

In addition to scale, the concept of marginal land has been important in the context of bioenergy crops. Marginal land has been described as land that is arable but either degraded or difficult to farm, and is often characterized as empty, idle, unproductive, and available for energy crops. The marginal designation is typically assigned to a given piece of land based on a combination of biophysical and economic characteristics (Shortall, 2013). However, the technical designation of marginal land is socially and politically constructed (Baka, 2013, 2014; Cope et al., 2011; Nalepa and Bauer, 2012). Narrow economistic and biophysical framings of marginality obscure the multiple land types comprising "marginal" land and the social-ecological interactions occurring there (Bailis and Baka, 2011), including non-economic valuations (Cope et al., 2011). As Bridge et al. (2013) noted, a transition to renewable energy sources such as energy crops produced on marginal land may require a significant shift in the "form, function,

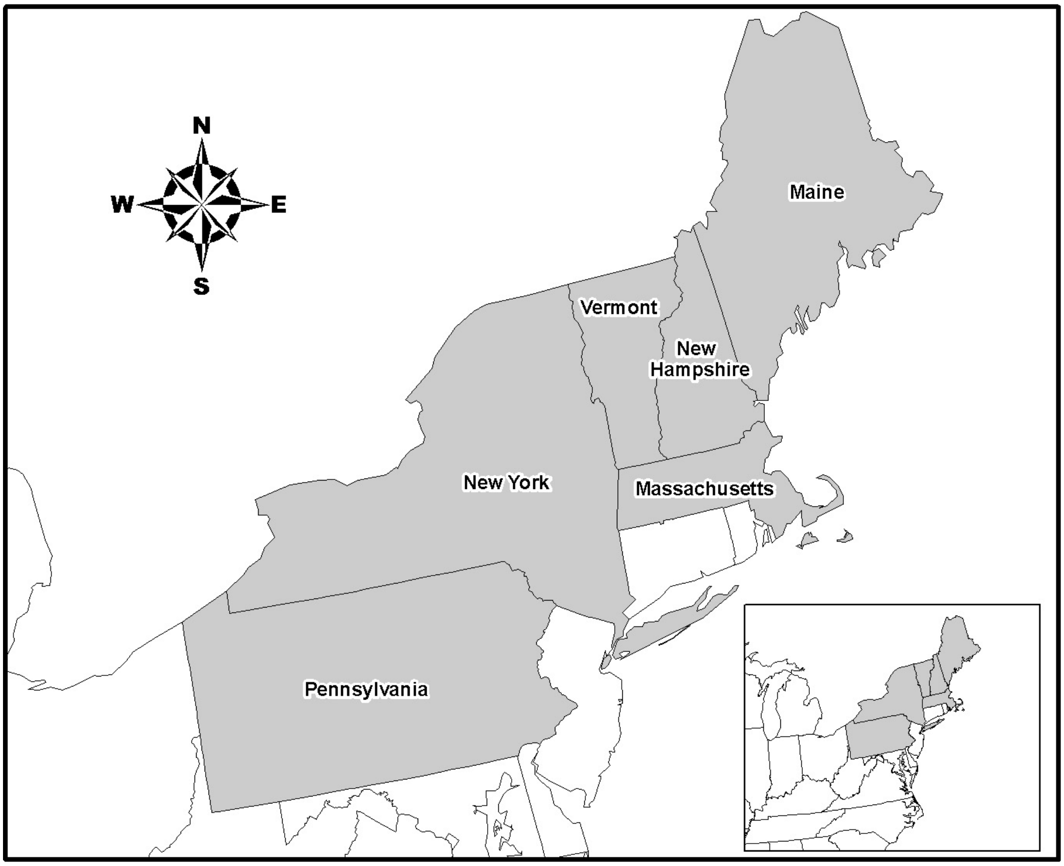

Fig. 1. Map of study area.

and value" of certain landscapes. Further, dominant conceptualizations of what constitutes marginal land and how it should be used often reproduce the normative social values that underpin different forms of economic activity and ideas about how land should be used (Walker and Fortmann, 2003). Thus, competing visions for and definitions of what constitutes marginal land become important points of contestation.

3. Study site

In this research, the Northeast United States refers to the region comprised of Maine, Massachusetts, New Hampshire, New York, Pennsylvania, and Vermont. Although bioenergy development trajectories vary globally, bioenergy actors in the Northeast have tended to focus on perennial energy crops on marginal land as feedstock for energy and renewable products. The Northeast region (see Fig. 1) is well-suited to perennial energy crop production because of its abundant rainfall and large amount of agricultural land that has fallen out of production (Stoof et al., 2015).

Table 1 provides an estimate of the marginal land available in each state for agricultural bioenergy crop production. Further, the region's high population, cold winters, and many poorly insulated houses lead to high energy demand, which in rural areas is typically met with fuel oil, accounting for nearly 85% of heating oil consumption in the U.S. (USEIA, 2014). Given the larger context of the need to mitigate climate change and reduce fossil fuel consumption, advocates see bioenergy as a way to replace heating oil with a less carbon intensive local energy source. Although replacing heating oil has been a strong focus in the region, biomass feedstocks are also seen as a potential fuel for electricity production and other bio-based products.

Table 1
Amount of potentially available marginal land for bioenergy crop production in the Northeast United States. Table adapted from Stoof et al. (2015).

State	Potentially available marginal land (10^3 ha)
New York	1015
Pennsylvania	838
Maine	356
Vermont	125
Massachusetts	125
New Hampshire	28

Several forms of agriculturally derived biomass production and use have developed in the Northeast, and each entails different production arrangements, scales, ecologies, participants, benefactors, and supply chain organization. We selected three states for study within the region—New York, Pennsylvania, and Vermont— because each has emerging agricultural bioenergy projects that capture a range of economic, cultural, agricultural, and landscape contexts. In New York State, shrub willow production is present on approximately 500 ha. Shrub willow production is supported by the United States Department of Agriculture's (USDA) Biomass Crop Assistance Program (BCAP), which was created by the Food, Conservation, and Energy Act of 2008 to promote the development of advanced biofuels from non-food or feed crops and provides a range of financial incentives designed to promote wide-spread biomass cropping and use. In 2016, one bioenergy company, Celtic Energy, participated in the program, and has rented land from several landowners to grow shrub willow. Their planting and harvesting efforts were supported by assistance from the State University of New York College of Environmental Science and Forestry. Through BCAP, the company contracted with ReEnergy Holdings LLC, who purchased the biomass they produce and blended it with forest biomass to produce power and heat. In 2013, ReEnergy produced about 1400 MW of electricity with the shrub willow biomass. The multi-institutional USDA-funded Northeast Woody/Warm-season

Biomass Consortium (NEWBio) has also targeted this region. Through BCAP and related projects, NEWBio's goal is to establish 40,000 acres of shrub willow as feedstock for various bioenergy applications. NEWBio's activities are not confined to New York, and they and their industrial partners have established approximately 5000 acres of miscanthus and switchgrass through land lease and production contracts in Pennsylvania and neighboring northeast Ohio, with the long-term goal of 50,000 acres.

In addition to NEWBio's activities, several smaller landowner driven bioenergy projects have emerged in the Northeast, including the New York Grass Cooperative (NYGC). The NYGC is a group of farmers who produce biomass pellets that are sold through direct markets, primarily for home-heating purposes. The NYGC had eight members, all former full-time dairy farmers unable to maintain their households on an agricultural income. Each still owned their land and either maintained a small sideline operation or rented their land to other farmers. Interested in how on-farm energy production could reduce fuel costs, a retired farmer and engineer started NYGC. Drawing on financial and technical assistance from county, state, and federal governments and other organizations, NYGC gained a contract to supply heating pellets to a local Department of Public Works garage, and built a mobile pelletizer. NYGC's production model entailed recruiting landowners who have fallowed land that has grown up into brush and weeds or who have hay crops ruined by rain to harvest the resulting biomass and then pay a fee to NYGC to use the mobile pelletizer to produce pellets to heat their own homes or be bagged and sold. Each member had purchased a multi-fuel stove for heating their home, which qualified them for federal tax incentives to defray the high investment costs. NYGC has continued to solicit new members, claiming that two acres of land provides enough biomass to heat an average home for a year, while costing 50 percent less than heating with oil.

4. Data and methods

Semi-structured interviews conducted between July 2014 and March 2015 with 42 bioenergy actors in New York, Pennsylvania, and Vermont involved with projects described above provide the main data for this study. To select study participants, we combined targeted and snowball sampling. As social science researchers affiliated with the NEWBio project, we asked project scientists to suggest industry representatives, policy and other decision-makers, representatives of farm interests and non-profits, and groups or individuals involved in agricultural bioenergy production and use in the Northeast. To recruit additional participants, all interviewees were asked to recommend other potential respondents. Although snowball sampling with interviewees initially identified by NEWBio researchers served to identify other possible respondents and built trust and rapport, it had several limitations. Snowball sampling is non-random and individual interviewees are chosen because of their affiliation with specific sociotechnical networks. Therefore, undue reliance on this method risks producing a homogenous sample where participants belong largely to the same epistemic network and professional categories (Browne, 2005). To ensure that interviewees in the study represented the range of agricultural bioenergy activity (and their attendant imaginaries) present in our study region, we asked interviewees to recommend other bioenergy actors who were involved in projects that differed in focus, scope, and scale from their own. We also identified other possible respondents through web-searches aimed at identifying bioenergy actors not mentioned to us by NEWBio researchers or our interviewees. Ultimately, 32 interviewees were identified through discussions with NEWBio researchers and snowball sampling, while the remaining ten were identified through our targeted sampling approach designed to identify alternative visions for bioenergy development.

Interview questions were designed to elicit respondent perspectives on the potential impacts of bioenergy development on communities and the environment, opportunities for and challenges to industry development, and best uses of and limitations to agricultural biomass as an energy source. Given the diverse positions, roles, and interests of interviewees, a semi-structured approach permitted flexibility in the focus of questions asked in each interview. Interviews were recorded, transcribed verbatim, and coded and analyzed using ATLAS.ti following the approach outlined in Friese (2014).

The coding process identified three major themes related to contested sociotechnical imaginaries among interviewed bioenergy sub-niche actors: (1) appropriate scaling of technology and production arrangements and its relation to imagined economic futures, (2) definitions of marginality, and (3) the use of dedicated energy crops and its connection to an imagined future good society. While these themes emerged from analysis of all 42 completed interviews, in this paper we focus on data collected from a group interview with NYGC members and participants (n = 8) and a case study of their model of bioenergy development that together demonstrate the conflicting sociotechnical imaginaries present in the region. The remaining key informant interviews offer supporting data for our analysis of the NYGC.

5. Results and discussion

5.1. Bioenergy sub-niches in the Northeast

Based on our interview data, the emerging bioenergy industry in the Northeast U.S. was comprised of two broad sub-niches, which we term: 'community energy' and 'regional production.' In the community energy sub-niche, farmers used conventional haying equipment to establish and harvest biomass crops, such as goldenrod or low quality hay, on small plots of land. Crops were stored as bales, densified into pellets or briquettes using small capacity stationary or mobile machines, and used to heat their own homes and farm buildings or sold locally on the consumer pellet market. In this model, the grower or a cooperative of growers generally owned the densification equipment and were responsible for marketing the densified material. Our study identified three different groups that either have implemented or attempted to implement a community energy production model, including the NYGC.

In contrast, in the regional production sub-niche, landowners contracted with fuel processors to provide biomass derived from perennial energy crops grown on marginal land. Arrangements in this sub-niche required much greater quantities of biomass to meet system needs than in the community energy sub-niche, meaning large acreages would need to be planted to realize this bioenergy vision. In one industry report, 2000 acres was labeled as a "good starting point" (Wilson Engineering, 2013). In the regional production sub-niche, briquettes and cubes processed from biomass materials are sold to industrial and commercial users who then combust these products for heat or coupled heat and power. Alternatively, undensified energy crops are sold to and combusted in a centralized power generation facility. Few examples of the regional production sub-niche are operational in the Northeast.

These community energy and regional production sub-niches are not mutually exclusive in terms of technologies used, biomass end-uses, and the scales at which they can be implemented. Several interviewed sub-niche actors worked across sub-niche boundaries, even while criticizing certain aspects of emerging sub-niches of which they were part. This blurring across sub-niches can be partly explained by the low number of agricultural bioenergy projects in the region, a situation that connected all sub-niche actors to one another through the common challenge of limited availability of resources and expertise for sub-niche construction. Moreover, several sub-niche actors supported all forms of bioenergy production and use. Thus, we recognize that categorizing the bioenergy sub-niches in our study region into binary models of community energy and regional production risks homogenizing them much as the MLP has been critiqued for treating niche spaces as

Table 2
Contested imaginaries in Northeast bioenergy sub-niches.

Community Energy Sub-Niche Bioenergy Imaginary	Regional Production Sub-Niche Bioenergy Imaginary
Local defined through community social relations and values	Local defined through transport infrastructure and carbon accounting
Local economic development	Economic development, climate mitigation, and renewable energy
Retains established land use systems, seeks to transforms dominant economic system	Retains dominant economic system; seeks to transform established land use practices
Prioritizes community, family, local benefits over regional or national needs	Prioritizes large acreages, centralized densification facility, economies of scale, dedicated energy crops, contracts
Challenges idea that regional model provides economic development that is locally beneficial.	Challenges idea that small scale is technically and economically feasible
Advocates for small scale, direct marketing options, grower control over bioenergy product, flexible land use	Dismisses viability of alternative visions

homogenous. However, given our interest in comparing competing visions for a good society through examining the intertwining of materiality and morality, we contend that our sub-niche binary captures two distinct sociotechnical imaginaries that broadly represents our interviewees' visions for bioenergy development. While the sub-niche actors who espoused these visions had distinct voices and favored different technologies and production arrangements to implement their sociotechnical imaginaries, their arguments converged around similar sets of thematic concerns.

Table 2 provides a summary of the two key contrasting visions for the best scale and land use features of bioenergy technologies to obtain a better future society identified in our interview analysis.

5.2. Scaling bioenergy imaginaries

We found that the community energy and the regional production sub-niches differed in their visions of the correct scaling of bioenergy production to produce desired goods. In our data, 'local' emerged as the key site for bioenergy development identified by our interviewees, setting general parameters for the scale of the emerging industry. However, sub-niche actors differed in their claims as to what should constitute local, with the primary points of contention arising over what production forms are best and what territorial area should be incorporated into biomass production to realize their imaginary.

Advocates of the regional production model defined local as biomass produced within 50–75 miles of the end user, or the greatest distance that most forms of biomass can be transported while being economically competitive and retaining carbon mitigation value. These actors envisioned a bioenergy future where contracted producers grow energy crops for a centralized processing facility that either densified the material and then distributed the product regionally or used it for power generation. Within this sub-niche, the parameters of what makes a bio-economy local were established through an economic threshold shaped by transport infrastructure and attendant costs, as well as by lifecycle analyses of carbon sequestration and emissions.

In contrast, the NYGC described their scalar vision with discourse reminiscent of other "localist" movements, such as local foods (Hess, 2009; Hinrichs, 2015). This vision was exemplified in their catch phrase, "eat local, heat local." The organization's imaginary emphasized establishing a locally sourced, direct market biomass economy where homeowners could go to the local farmers market to buy both food and fuel, or otherwise purchase finished biomass products directly from the cooperative. As one member explained:

> That is the point of the 'buy local' concept. The farmers market, you go there for your food and your heat. Pick up some bags of pellets while you are there…[That] is the 'eat local, heat local' idea. [Or if you] are going through a CSA to buy your produce from a local farmer, you could also buy your heating fuel from him.Interview 27

For NYGC, "heating local" further implied that biomass production should benefit producers first—not processing, distribution, retailing, or other supply chain actors. One member told us:

> The point of this [bioenergy development] is to get farmers another source of income out of their farms. Design the program so the farmer can utilize this as an income source and derive a profit from it.Interview 20

NYGC participants articulated concerns about the uneven accumulation of capital in the hands of corporations and large landowners if the regional model were more fully implemented. As one member cautioned, the community energy model is important because, "That way you can ensure the farmer can make the profits. If you do one big installation, then massive acreage has to be planted and only one person is satisfied" (Interview 21). In contrast, NYGC participants invoked their localist vision of a good society and imagined an energy production and consumption model that reclaims economies from large-scale corporate interests by building direct relationships between growers and end-users. Key to achieving this vision is group ownership and operation of mobile pelletizers. For NYGC, using a group-owned pelletizer as opposed to a centralized individually or corporate-owned densification plant meant that small growers would retain production value. As the NYGC stated, "By keeping our operations fully mobile, we remove the need for a middleman—the stationary mill—and put all profits into our producers' hands." Likewise, on farm-processing of biomass and direct marketing help to eliminate the need for middlemen to transport biomass. NYGC's vision can be interpreted as a critique of extant relations of agricultural production. As one group member explained:

> Now that we see big goes bad and our government fails us more times than it has success, we start to say, if we keep this local and keep this in a closed loop within a [small] radius, it works. Keep it small; keep it local.Interview 19

For NYGC, the mobility and flexibility provided by the mobile pelletizer and direct marketing meant that growers retained the power to decide what to do with their end product, while also ensuring a higher profit. Other Northeast community energy actors made similar claims, such as an interviewee who started a (now defunct) bioenergy cooperative to overcome the unfair price farmers received for their switchgrass from a densification company:

> They [the end user] had a fellow from New England [whose company processed the switchgrass into briquettes], but was paying the farmer peanuts for the switchgrass. And, as a group of farmers with switchgrass, we got together to form a cooperative and control our own destiny and stick together in terms of negotiating prices and so on.Interview 35

As this quote suggests, the cooperative model enabled a smaller production scale—in this case, the cooperative purchased a pelletizer and signed a contract to deliver pelletized switchgrass to a local school district. Other landowners who had started a small bioenergy cooperative in the Southern Tier of New York also critiqued the scaling of larger production models. These claims not only challenged the practice of accepting low payments for agricultural crops, but contested justifications enlisted by the dominant bioenergy imaginary. Consider the statement from a cooperative founder whose vision was premised on producing bioenergy products for their own use, thereby keeping bioenergy production as small and local as possible: "As soon as you get large scale, you have to deal with the problems it creates" (Interview 17). Here, local bioenergy production was envisioned in moral terms and positioned as an alternative to national and global energy relations, representing an opportunity to forge a more sustainable economic model:

> And the alternative economic model I saw was the cooperative. So, it's not just biomass. I think biomass can fit in with a whole lifestyle, a whole different economic way of handling things. It would be a mistake to take the biomass and put it in the old economic model. It needs to change the way America's doing business. Then it fits.Interview 17

As this quote underscores, the good society community energy actors imagined bioenergy development enabling is one that not only transforms energy systems but also transforms economic systems to achieve localist goals. Further, this good society is distinctly tied to production choices; for them, equipment and scalar choices are inextricably linked to whose imaginary is enacted. In this way, community energy actors articulated a moral imperative related to production system design choices. Claims of this sort also resonated with a minority of regional production model actors. As one interviewee who directed a large federal program designed to enroll farmers and landowners into planting energy crops explained:

> With any new industry there come all kinds of new business arrangements, and a lot of the business arrangements are very entrepreneurial. And growing those arrangements and making sure everybody is above board in how they are behaving is a challenge… In our program, funds are supposed to be delivered and be a benefit to the landowner, the operator… [but] to keep the landowners being the benefit of the new industry is a challenge.Interview 30

This interviewee also explained that a major challenge they have faced is growers terminating their contracts with centralized processing facilities because the prices they receive for their energy crops are too low. Thus, actors outside of the community energy sub-niche also recognized the distributional politics of scaling bioenergy. However, our findings uncover an important distinction: community energy actors have actively sought to mitigate these problems by envisioning and realizing alternative bioenergy production and consumption arrangements. On the other hand, regional production sub-niche actors tended to naturalize the problem of low payments for growers as an inherent challenge of a new industry, and appeared content to allow distributional disparities to work themselves out.

5.3. Justifying small scales

In the community energy sub-niche, the word "local" (and by extension scale) was used to signify both a vision of the appropriate size and spatial extent of bioenergy development and a series of cultural values around which an emerging bioenergy economy should be built. NYGC's community energy model was envisioned as means to build relationships between customers and growers and maintain the rural, agricultural feel of their communities—visions which aligned with localist food and farming movements. For example, one NYGC member explained part of his motivation for joining the group was his county's rapid urbanization, which he saw as driving up living costs and transforming the landscape's bucolic character. For him, small-scale bioenergy crop production was a way to keep "family farms" viable, while curbing urban growth:

> "People would rather see open farmland next to them rather than the farm being sold and a big housing development coming in; more kids coming in. Now we gotta build more schools, more taxes, more police departments."Interview 20

Likewise, another member explained his vision for a good society by describing how the NYGC model would establish a close-knit community of farmers, stove retailers, and local consumers in his community: "As more of these multi-fuel units are sold by retailers, there will be referrals to local farmers. So that it is a locally-based industry. And these purchasers will go to a local farmer to buy fuel" (Interview 19). This localist vision for farmer-consumer relationships contrasted starkly with reliance on the impersonal centralized energy production and consumption model advocated for by the regional production sub-niche actors.

Other community energy sub-niche actors in the Northeast articulated similar concerns about the differences between their scalar imaginary and those narrated by the regional production sub-niche. For example, the thorny nature of cultural versus economic/environmental framings of what constitutes local was well-explained by an NGO employee whose work focused on environmental and economic development:

> [The regional production model] doesn't match the scale of Vermont… We like things small and local, but they [referring to the Wilson Engineering report] don't see it that way…I think it is a smaller scale that we need to focus on. What is really interesting to me is it [community energy] is the one model recommended against in Wilson Engineering's report. … They don't think it is economical, that it is never going to work or pencil out…. I had to really push to get the [community energy] model included…They were really making fun of me about it. You know, cutesy, hippy-dippy Vermont …What is interesting is that on-farm, closed loop processing is the only version of grass energy happening in Vermont. That says something I think.Interview 4

Similarly, the bioenergy economy was again connected to localist food movements by a Cornell Cooperative Extension employee who posited, "it [bioenergy] can scale. It just depends on what your priorities and values are" (Interview 47). She explained that connecting bioenergy to local foods movements provides opportunities for changing how economies are organized, how accountability for environmental and social problems is determined, and how independent and sustainable communities are created. She argued that the regional model of production does not "connect to communities in this way." The line of contrast between these visions can be drawn as such: the regional production model was premised on an implicit prerequisite for obtaining an imagined "economy of scale," which was assumed to be necessary for succeeding within existing energy markets. In contrast, the vision of community energy model actors can be interpreted as a *reimagining* of energy systems and markets as means to connect communities, economies, and actors rooted in shared localities.

5.4. Contesting the community energy model imaginary

The primary argument regional production model actors put forth against the community energy model's viability was that it does not "pencil out" (Interview 31) financially. This critique took several forms. First, as argued in a report commissioned by Vermont Sustainable Jobs Fund and written by the Pennsylvania-based firm Wilson Engineering, the community energy model was deemed incapable of achieving the "economies of scale" necessary to achieve cost-reducing efficiencies (Wilson Engineering, 2014). Second, others argued technical challenges, including the high ash content of grasses and the challenge of designing economically priced technologies that can successfully burn grasses while keeping air emissions low, made the community model obsolete. As one New York State Energy Research and Development Authority (NYSERDA) representative explained, "you really need some sophisticated pollution control and ash handling equipment to be able to burn [grasses]" (Interview 14), arguing that expenses associated with the emissions control technologies required to meet air quality standards would be too high to "operate on a neighborhood scale."

The Wilson Engineering report's framing of the challenges and opportunities for implementing grass energy production and consumption systems the Northeast was well-known within the grass energy community. Many interviewees referred to the report as the best available knowledge for understanding the future of grass energy production system pathways in the Northeast. In New York, NYSERDA has played a role in bioeconomy development through dispensing grant money for bioenergy projects. By conceptualizing small-scale community energy as uneconomical and not scalable, the discourse employed by Wilson Engineering, NYSERDA, and other regional production sub-niche actors worked to naturalize a form of bioenergy production (i.e., the regional production model) most amenable to the area's extant scaling of commercial agriculture, while rendering the community energy model unattainable because it could not successfully function within the larger economic and regulatory context. In this way, regional production model actors deployed accepted regime level ideas about how the economy and technology work, referred to as "rules" and "expectations" (Geels and Schot, 2007; Raven and Verbong, 2009) in the MLP literature, to dismiss the ability of the community energy model to succeed while legitimizing themselves. By enacting economic rules about scale to dismiss the community energy model and circulating them in reports and other forms of discourse such as interviews, regional production actors will likely constrain possibilities for the community energy model to be accepted. Because the bioenergy economy in our study region is nascent, these public critiques have been fairly limited thus far. However, the power of the scalar arguments embedded in the Wilson Engineering report over bioenergy niche development are already evident on the Vermont Sustainable Jobs Fund's website, where the report's results are referred to as "key recommendations on models of grass energy that will work best for Vermont" (VSJF). This assessment privileged the regional production model, while omitting mention of alternatives because the alternatives violated the regime's economic rules and expectations.

5.5. Marginal land and dedicated energy crops

The availability of marginal land has been central to the regional production sub-niche's imagined good society in which bioenergy functions to simultaneously mitigate climate change and revitalize flagging rural communities. The key natural resource endowment on which the imaginary is constructed is the assumed widespread availability of low productivity or abandoned farm and pastureland for energy crop production.

Northeast bioenergy actors in this study defined marginal land in four main ways—what we term biophysical, economic, temporal, and social marginality. The dominant framing of marginal land posited by regional production sub-niche actors coupled biophysical and economic marginality. For them, biophysically marginal land was land that is difficult or unfit for most forms of crop production because it is too steep or sandy, has high soil acidity and low nutrient capability, or has poor drainage. Economic marginality referenced formerly productive but now underused or idle agricultural land where crop revenue would be equal to or under the cost of production. In the words of one interviewee, this land "just sits there" (Interview 12), and bioenergy crops provide a way to profit economically it. Another explained:

> I think [there are] a lot of opportunities in New York State [for developing a regional model of production] …We have something like 2 million acres of marginal soils that aren't used right now.Interview 6

These visions of marginality deemed land available for bioenergy production because it was economically unproductive, or because it could be used to generate more profit than it did presently. While interviewees who framed marginal land in biophysical and economic terms appeared to recognize that the status of a given piece of marginal land might shift (given technological, policy, or economic factors), their conceptualization of marginality relied on the belief that land values and use are best determined by economic returns. This was evinced by their frequent use of the word "idle" to describe marginal land. For example, one regional production sub-niche actor involved in the development of a torrefaction plant saw biomass crops as a good fit for the region because:

> There are a couple of thousand acres [of old pasture from a defunct dairy industry in a town adjacent to the plant]… a lot of it doesn't even get cut anymore…most of it is just left standing. One hundred years from now, there will be some trees growing, but it won't be producing. It won't be a commercially viable forest.Interview 29

Here, the regional production sub-niche treated marginality as a fixed category, in effect ignoring human-environment relations that fall outside the boundary of economic considerations and how these are related to different visions of what a good society should be.

In contrast, NYGC and other community energy actors, particularly active farmers, discussed marginal land in temporal and social terms. They recognized the continually shifting status of marginality as something contingent on year-to-year production factors, including weather, insect damage, and crop prices. When asked to define marginality, one NYGC member explained:

> One of the things you will see is that every farmer has mixed stories about [their] fields. And the conditions aren't the same year-to-year. I look at my farm and I have got fields that were dry as anything this year that we didn't get a second cutting off of. I have got weeds. Those weeds that grow up would be ideal for pelleting. Others years you have abundant rain in August and September, you get a beautiful second cutting and you sell it for $200–250 a ton. This year it could become pellets. It is not a uniform situation year-to-year.Interview 21

In contrast to the more static imaginary advocated by regional sub-niche actors, this provisional definition of marginality and its accompanying vision for bioenergy production sought to maintain flexibility and adaptability within an inherently variable farming system. In this lay the grounds for contesting the use of long-term dedicated grass energy crops for bioenergy production. Much like their arguments about scaling, NYGC connected their arguments about marginal land and how it should be understood and used to their localist socio-technical imaginary, which aimed to reduce outside, corporate control of the agricultural economy, retain profits for producers, and forge close-knit relations between farmers and their community. NYGC envisioned a future where bioenergy was incorporated into existing practices and attuned to seasonal patterns—a production system made possible through mobile pelletizer technology. Rather than sending unprocessed energy crops off the land, production happened on-farm with the mobile pelletizer—a tool capable of extracting value from rain-damaged hay crops, unproductive second cuttings, or fields that needed to be mowed either to keep shrubs out or to prepare ground for seeding with forage crops. As one interviewee explained, "it [NYGC's vision] is the use of a non-productive field, one that is not ready for production; it is also an output for hay that has gotten wet or ruined that can't be of forage value." NYGC's vision for which crops should be used for energy production was well-summarized in another of their catch phrases, "if it's not palatable [for livestock], it's pellatable."

Further, using low quality hay and forage crops for pelleting rather than planting dedicated energy crops was seen by NYGC as a way to hedge against the risk of crop failure by capturing the highest possible production value from their fields in a particular year. Because market prices for forage crops were significantly higher than dedicated energy crops, using low quality forage crops or the material from mowed fields ensured farmers received the maximum possible profit from a field in any given year by providing a second market option, allowing them to capture value from crops that would otherwise be lost:

> If I was doing a new planting today, I would not put in switchgrass. I would put in the highest productivity hay I can get out of it because that is your highest value. It is going to cost you the same basically to seed no matter what you put in there. If you put switchgrass in, what are you going to do with it besides bioenergy? You put in a good haymaker mix or alfalfa that you can sell for five bucks a bale [if it is good quality], that is your first choice if you are going through all the effort of reseeding.Interview 27

In contrast to the regional production sub-niche actors, who advocated for the development of a new agricultural production system based on dedicated energy crops, bioenergy made sense for community energy sub-niche actors only because it could be incorporated into their existing farming systems, increasing flexibility and reducing risk, rather than entailing commitment to an entirely new agricultural production system.

The community energy sub-niche framing of marginality also occurred in interviews with farmers not part of NYGC who used so-called marginal land to achieve flexibility and accomplish non-economic land management goals, such as providing habitat and forage for wildlife, what we call social marginality. For example, when asked whether he would be willing to put his approximately ten acres of marginal land into energy crop production, a dairy farmer who grew grass for hay, corn, and soybeans explained that although the land was biophysically marginal, he always planted it in corn to provide food for wildlife because his family hunted and liked having wildlife on the property: "I always plant it. Sometimes you harvest it and sometimes you don't. But like I said, I am going to leave some for the deer anyway. We take care of the wildlife" (Interview 37). He went on to explain that in years when he can get a harvest off the marginal land, he does so while leaving an equal amount of corn on his prime agricultural land that provides better deer habitat. Thus, in good years, the marginal land was planted in corn and harvested to offset the acreage left in corn to provide food for deer, while in bad years he left the unharvested corn in the ground for deer and harvested the crop from the prime land. Adaptive and intentionally flexible uses of land—marginal and otherwise—were common practice for many landowners in this study. This contrasted with the vision regional production sub-niche actors had of biophysically and economically marginal land being readily available for bioenergy crops, a contrast explained by a consultant hired to assess the viability of establishing a bioenergy economy in Central New York:

> Some of this marginal [land] is owned so they can hunt on it, so they can ride their four-wheeler, so they can take nature walks. In that study we found that one parcel is not all flat, loamy, tillable crop land and then the next parcel is all marginal. Most parcels have a mix. So in many cases, they rent out the good land to a local farmer and the rest of the land remains brushy and doesn't get used, and the idea of someone coming in and plowing and putting a permanent crop in and disrupting that area that they use for those other things… anything that goes on on their land, whether it is noise, dust, or just a long term commitment that doesn't fit with the other reasons they own the land, such as recreation, it was in the family, if it doesn't fit with those reasons then they are not interested.

This quote demonstrates that even those outside of the community energy sub-niche proper may contest the idea that biophysically and economically marginal land is readily available for energy crop production. Instead, the good society that they imagine is one where land not only provides economic returns but also provides habitat for wildlife or space for recreational activities, which directly contrasts with the regional production model's vision for a good society which renders marginal land valuable solely for pecuniary reasons.

6. Conclusions

We have enriched the MLP on sociotechnical transitions by using literatures on contested imaginaries and object conflicts to consider the politics of rival imaginaries for obtaining better future societies through the development of bioenergy technologies. By developing our *politics of imaginaries* concept, our analysis revealed two key contrasting visions regarding the best scaling and land use features of bioenergy technologies for obtaining a better future society. Community energy sub-niche actors envisioned a small-scale bioenergy system where bioenergy crops were produced and consumed largely within the community, and land use and cropping decisions were dynamic and flexible. According to this vision, bioenergy technologies should enable localist priorities and reduce outside control over the agricultural economy while keeping profits in the hands of producers and engendering close-knit community relations. In contrast, regional production sub-niche actors envisioned a more sweeping land use transformation, while maintaining typical grower-corporate relations, in order for bioenergy to compete with other technologies in the field of energy use in the Northeast. The success of this vision is premised on enrolling actors in a collective imaginary of energy independence, climate change mitigation, and rural economic development dependent on and driven by decision-makers unfamiliar to community residents.

Our analysis of contested imagined futures drew on the concept of scaling to investigate how bioenergy sub-niche actors connect issues of technological choice, economic organization, and land use decisions to their sociotechnical imaginary for bioenergy development. However, the assumption that there is anything inherently good or bad about local, regional, or national scales has been challenged in the literature. As Born and Purcell (2005, 195) point out, local or larger-scale agricultural systems are "equally likely to be just or unjust, sustainable or unsustainable." Rather than scale, this literature has recognized that agricultural system outcomes are contextual and determined by "actors and agendas that are empowered by the particular social relations" (196) in a system. Assumptions about the benefits of local ownership have also been challenged in the bioenergy literature, with work on local ethanol plant ownership in the Midwestern U.S. providing a caution against simplistic narratives that privilege the local scale as inherently advantageous for communities (Bain, 2011). Nevertheless, our findings underscore the depth of participants' beliefs about the importance of scaling to achieving their sociotechnical imaginary.

We view object conflicts over scaling and their attendant sociotechnical imaginaries not as roadblocks to either the regional production or community energy model's development, but rather as fruitful points of entry for engaging industry, scientific, and other stakeholders in the project of envisioning how a better future society can be obtained through bioenergy development. In 2016, bioenergy development and infrastructure in the Northeast remained nascent—although momentum has continued to gather as interest in perennial grass bioenergy crops as tools for improving water quality and conservation efforts grows. This momentum provides an opportunity for the development of a mutually agreeable hybridized bioenergy niche in the Northeast U.S.

As the MLP literature reports, heterogeneity and conflict between sub-niches is not necessarily bad for niche technology development. Indeed, conflict can shape sociotechnical transitions toward more just and sustainable ends. In our case study, the scalar and technological arrangements in place within each bioenergy sub-niche can and do overlap, showing it is possible for them to co-exist from a technical perspective. However, this may not be the case from the perspective of the sociotechnical imaginaries each seeks to implement, and it remains to be seen if the competing sub-niche imaginaries in the Northeast U.S. can coexist or if one crowds out the other. Regimes often place limits on sub-niche possibilities through the expectations and rules they create (Raven and Verbong, 2009), thus limiting the ability for a sub-niche that contradicts them to influence regime change. Because the regional production model fits within regime rules and expectations (while deploying them to discredit the community energy model), it is more likely that it will influence the trajectory of the bioenergy transition in the Northeast because it can more easily be incorporated into the regime (Geels and Schot, 2007).

However, as Geels and Schot (2007) point out, niche development is driven by heterogeneous sociotechnical practices by various sub-niche actors. When there is heterogeneity between them, it is possible that subtle or even major changes to the rules and expectations that sub-niches draw on to inform their development can change or converge, leading to either co-existence or even a single niche alternative acceptable to all parties. This may occur in one of several ways. The first is through competitive market processes. The second is through negotiation and coalition building between sub-niche actors (Geels and Schot, 2007). As the trajectory of niche development and regime realignment in the MLP suggests, one sub-niche innovation will eventually become dominant and form the primary sociotechnical configuration that reconfigures the regime. Through a process of negotiation and coalition building among bioenergy sub-niche actors in the Northeast, it is possible that this final niche could take a form that brings together the sociotechnical imaginaries present in the regional production and the community energy models in a way that is acceptable to both. This would require both regional production and community energy sub-niche actors to soften the economic assumptions they attach to differently scaled bioenergy economies. In this way, scale would no longer be the assumed key determinant of the sociotechnical imaginary that bioenergy development is able to engender. Rather, a shared agenda and understanding across the sub-niche camps would enable a mutually acceptable transition. While there is currently little interaction between the two sub-niches, a shared understanding of what sociotechnical imaginary bioenergy development in the Northeast should put in place may occur as the debate between the regional production and community energy model begins to play out in social-institutional arenas such as conferences, journals, workshops, and grant competitions (Geels and Schot, 2007). An example of what a shared niche sociotechnical imaginary might look like would be establishing cooperatives of community energy actors to provide the biomass feedstocks needed to run the larger-scale biopower facilities advocated for in the regional production model. This may mitigate community energy actors' concerns about corporate control over profits while abating regional production model actors' concerns that small operations are not economically viable. This model is already present amongst wood bioenergy economies in the Northeast and thus represents a realistic path forward.

Acknowledgements

We acknowledge support from the Northeast Woody/Warm-season Biomass Consortium (NEWBio). NEWBio is supported by AFRI Competitive Grant No. 2012-68005-19703 from the USDA National Institute of Food and Agriculture. Our funding source had no role in study design, interpretation of data, or the decision to submit this article for publication. We would also like to thank our three anonymous reviewers for their insightful comments, which significantly improved the manuscript. We also thank James Spayd of the Penn State Institutes of Energy and the Environment for assistance with the map.

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