Building Bio-based Supply Chains: Theoretical Perspectives on Innovative Contract Design

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ABSTRACT

By 2030, the United States will consume over 300 million tons of forest and agricultural feedstocks for energy production. The supply chain necessary to provide unprecedented quantities of new "bioenergy crops," however, is fraught with uncertainty. The vertically integrated model currently used by the nascent sector may have limited opportunity for expansion to meet renewable energy mandates. A hybrid structure is likely to emerge as the industry evolves, in which end-users closely cooperate with a large number of heterogeneous producers through long-term contracting rather than as direct owners or operators of biomass farms. This "vertically coordinated" industry model is dependent on a series of biomass supply contracts between end-user and farmer. The "take it or leave it" production contracts offered by end-users represent the archetypal cost- and risk-minimization perspectives common in the fossil fuel-based energy context (e.g., petroleum, coal). These initial offerings lack many of the

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considerations provided in agricultural-based contracting and are unlikely to engender the level of dedicated energy biomass cultivation needed to meet renewable energy mandates. In response, we propose an alternative Biomass Contract Framework, which incorporates three separate theoretical approaches to contract design with the objective of removing barriers to entry into the market. Incorporating a socioeconomic perspective into the more familiar risk- and cost-minimizing approaches found in contract theory literature will enhance producer ability to maintain existing social networks, while minimizing farmer disincentives to enter into production contracts for novel biomass crops. Our Framework also recognizes end-users' needs to meet emerging environmental sustainability requirements, even perhaps facilitating "shed-level" coordination.

I.
INTRODUCTION

A robust mix of domestic and international policies increasingly recognize the importance of renewable energy in combating climate change, achieving energy independence, and stimulating rural redevelopment. In addition to wind and solar power, biomass-based energy from crops and forests holds significant untapped potential. Projections indicate that by 2030 the U.S. will consume 329 million dry tons of forest and agricultural feedstocks for energy production, primarily for co-firing electricity generation facilities.[1] State renewable portfolio

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[1] U.S. DEP'T OF ENERGY, OAK RIDGE NAT'L LAB., U.S. BILLION-TON UPDATE: BIOMASS SUPPLY FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY 14-15 (2011) [hereinafter USDE, BILLION-TON UPDATE], *available at* http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf.

standards[2] and limits on stationary source emissions of greenhouse gasses (GHGs)[3] are incentivizing electricity generators and other large emission sources to seek out a long-term, reliable supply of combustible agricultural and forest biomass.[4] Likewise, mandates embedded within the federal Renewable Fuel Standard (RFS2)[5] will require significant

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[2] The U.S. Department of Energy summarizes state renewable energy portfolio standards as a percentage of electricity sales or absolute capacity by megawatts (MW) as follows: AZ, 15%; CA, 33%; CO, 20%; CT, 23%; DC, 20%; DE, 20%; HI, 20%; IA, 105 MW; IL, 25%; MA, 15%; MD, 20%; ME, 40%; MI, 10%; MN, 25%; MO, 15%; MT, 15%; NH, 23.8%; NJ, 22.5%; NM, 20%; NV, 20%; NY, 24%; NC, 12.5%; OR, 25%; PA, 8%; RI, 16%; TX, 5,880 MW; WA, 15%; WI, 10%; additionally, five states, ND, SD, UT, VA, and VT, have voluntary non-binding goals. *See* U.S. Dep't of Energy, *Renewable Portfolio Standard Policies with Solar/Distributed Generation Provisions*, DATABASE OF ST. INCENTIVES FOR RENEWABLES & EFFICIENCY (DSIRE), http://www.dsireusa.org/documents/summarymaps/Solar_DG_RPS_map.pdf (last updated February 2013); *see also* U.S. Dep't of Energy, DATABASE OF ST. INCENTIVES FOR RENEWABLES & EFFICIENCY (DSIRE), http://www.dsireusa.org/.

[3] Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31514 (June 3, 2010) (to be codified at 40 C.F.R. pts. 51, 52, 70, et al.), *available at* http://www.gpo.gov/fdsys/pkg/FR-2010-06-03/pdf/2010-11974.pdf.

[4] *See, e.g.*, Ira Altman et al., *Contracting for Biomass: Supply Chain Strategies for Renewable Energy* (Feb. 2006), *available at* http://ageconsearch.umn.edu/bitstream/34907/1/sp07al01.pdf (unpublished paper for presentation) (on file with author) (describing Iogen Cooperation); Melody M. Bomgardner, *Abengoa Advances Cellulosic Biofuel*, 89 CHEMICAL & ENG'G NEWS 26, 26 (2011).

[5] 40 C.F.R. §§ 80.1100-80.1167 (2012). The Energy Independence and Security Act of 2007 mandates that by the year 2022, gasoline blenders will incorporate at least 36 billion gallons of renewable fuel into the U.S. fuel supply, 16 billion gallons of which must qualify as advanced biofuels. Energy Independence and Security Act, Pub. L. No. 110-140 § 202 (codified at 42 U.S.C. § 7545(o)(2)(B)(i) (2007)). The RFS2 implementing regulations defines renewable fuel as a fuel produced from grain; starch; vegetable; animal or fish materials; sugarcane, sugar beets or sugar components; tobacco; potatoes, other biomass; or natural gas produced from a biogas source, such as a landfill, sewage waste, feedlot, or other place with decaying organic material. 40 C.F.R. § 80.1101(d) (2012). As a subset of renewable fuel, the RFS2 defines cellulosic ethanol as ethanol derived from any cellulose, lignocellulosic, or hemicellulosic matter from dedicated energy crops or trees; wood and wood residues; plants; grasses; agricultural residues; and animal wastes and municipal solid waste that has lifecycle greenhouse gas emissions at least 60% less than the fossil fuel baseline. 40 C.F.R. §§ 80.1101(a), 80.1401 (2012). Advanced biofuels include cellulosic biofuels, and any renewable fuel other than ethanol derived from

biomass supplies to produce up to sixteen billion gallons of advanced biofuels each year. On the supply-side, the Biomass Crop Assistance Program (BCAP) attempts to link agricultural producers of crops, such as *Miscanthus*, switchgrass, hybrid poplar, and camelina with qualified biomass conversion facilities.

Mandates and subsidies aside, scholars who have empirically evaluated producers' willingness to participate in the biomass industry have unearthed a plethora of critical issues that farmers face in the adoption of energy crops.[6] Producers unfamiliar with novel cropping and harvesting practices must adopt new techniques and invest in production infrastructure that is costly and involves substantial risk. Adding to the novelty of a perennial cropping system is the likelihood that producers will be obligated to meet environmental and social sustainability requirements incorporated within bioenergy policies. For example, the European Union's Renewable Energy Directive requires sustainability certification to protect against conversion of high conservation and carbon value lands, and agricultural

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cornstarch that obtains a 50% reduction in greenhouse gases over the baseline emission of fossil fuels. 40 C.F.R. § 80.1401(3) (2012).

[6] *See, e.g.*, Kimberly Jensen et al., *Farmer Willingness to Grow Switchgrass for Energy Production,* 31 BIOMASS & BIOENERGY 773 (2007); Susanne Paulrud & Thomas Laitila, *Farmers' Attitudes About Growing Energy Crops: A Choice Experiment Approach,* 34 BIOMASS & BIOENERGY 1770 (2010); Alissa M. Rossi & C. Clare Hinrichs, *Hope and Skepticism: Farmer and Local Community Views on the Socio-economic Benefits of Agricultural Bioenergy*, 35 BIOMASS & BIOENERGY 1418 (2011); Maria B. Villamil et al., *Potential Miscanthus' Adoption in Illinois: Information Needs and Preferred Information Channels*, 32 BIOMASS & BIOENERGY 1338 (2008); Patricia C. Hipple & Michael D. Duffy, *Farmers' Motivations for Adoption of Switchgrass, in* TRENDS IN NEW CROPS & NEW USES, at 252 (Jules Janick & Anna Whipkey eds., 2002); John C. Tyndall et al., *Corn Stover as a Biofuel Feedstock in Iowa's Bio-economy: An Iowa Farmer Survey,* 35 BIOMASS & BIOENERGY 1485 (2011); L. E. Holloway & B. W. Ilbery, *Farmers' Attitudes Towards Environmental Change, Particularly Global Warming, and the Adjustment of Crop Mix and Farm Management,* 16 APPLIED GEOGRAPHY 159 (1996); Chris Sherrington et al., *Farm-level Constraints on the Domestic Supply of Perennial Energy Crops in the U.K.*, 36 ENERGY POL'Y 2504 (2008); Raymond Costell & Janine Finnell, *Institutional Opportunities and Constraints to Biomass Development*, 15 BIOMASS & BIOENERGY 201 (1998); Christine Rosch & Martin Kaltschmitt, *Energy From Biomass—Do Non-Technical Barriers Prevent an Increased Use?*, 16 BIOMASS & BIOENERGY 347 (1999).

pollution.[7] U.S. producers seeking to access Europe's emerging renewable energy market must obtain third-party certification under an approved sustainability standard. Domestically, the RFS2 excludes biofuels derived from newly converted agricultural or forest land[8] and, depending on the outcome of U.S. Environmental Protection Agency (EPA) studies,[9] may require in the future some form of sustainability accounting.

Although organic certification has been available in the U.S. for two decades, and some environmental requirements already apply on certain agricultural lands, the vast majority of potential biomass producers in the U.S. are not familiar with sustainability requirements or production certification schemes of any type.[10] Compounding uncertainty are the diverse set of end-users obligated to achieve GHG reductions under bioenergy statutes—ranging from petroleum refiners to biofuels power generators—most of whom are unfamiliar with rural culture and agricultural practices. All these barriers to adoption stand in the way of more rapidly developing the nation's bio-economy. Moreover, potential biomass producers consistently voice concerns related to risk, cost, and the negative impacts on social networks when discussing abandonment of traditional commodity crop production in favor of bioenergy feedstocks.[11]

Contractual agreements are one way to address these concerns and bring together growers and end-users to reduce uncertainty on both sides of the equation. Scholars from the disciplines of economics, finance, rural sociology, and the law have developed generalized theoretical approaches to contracting from risk-minimizing, cost-minimizing, or sociological-

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[7] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, 2009 O.J. (L 140) 16.

[8] 42 U.S.C. § 7545(o)(1)(I) (2012) (providing a definition for "renewable biomass").

[9] Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 204(a), 121 Stat. 1492, 1529 (2007).

[10] Jody M. Endres, *Agriculture at a Crossroads: Energy Biomass Standards and a New Sustainability Paradigm?*, 2011 U. ILL. L. REV. 503, 516–17 (2011).

[11] Rossi & Hinrichs, *supra* note 6, at 1418.

compatibility perspectives. In the rapidly evolving world of renewable energy, it is clear that existing theoretical approaches may not address adequately the new challenges of a bio-based economy. Rather, a comparative analysis of the focused, goal-specific orientation of each disciplinary perspective has enabled us to identify potential areas of conflict that, within the defined space of biomass production contracts, may engender significant barriers to innovation adoption—obstacles that a developing industry must overcome in the near term in order to secure sufficient biomass supply to meet demand.

Categorizing and approaching potential issues from the perspective of the biomass producer has allowed us to develop a novel, interdisciplinary Biomass Contract Framework and methodology to address farmer concerns in a systematic manner. The framework facilitates contracting parties' ability to identify tradeoffs and strike balances between conflicting contractual goals when applied to biomass-specific issues. Accordingly, the development of the Biomass Contract Framework provides greater theoretical understanding to the development of biomass supply chains and the importance of contract design to facilitate reliable sources of renewable energy. And, although the specific context of this article remains the biomass supply chain for renewable energy production, this framework could apply in other supply chain contexts involving similarly innovative end-products and disruptive technologies.

Part II describes foundational, theoretical considerations taken into account in the Biomass Contract Framework. Part III outlines the framework within the context of two leading biomass feedstocks—perennial energy grasses and corn stover.[12]

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[12] Corn stover is the residue left behind after the corn harvest, consisting primarily of leaves, stalks, and cobs. *See* John Sheehan et al., *Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol*, 7 J. INDUS. ECOLOGY 117, 117 (2004). Currently, corn stover comprises the largest quantity of biomass residue in the United States, the majority of which is produced in the Midwest. R. L. Graham et al., *Current and Potential U.S. Corn Stover Supplies*, 99 AGRONOMY J. 1, 6 (2007).

Two leading perennial energy grasses are switchgrass (*Panicum virgatum*) and *Miscanthus*. Switchgrass is a warm-season perennial grass that is native to most of North America, and commonly grown for forage and grazing. Jensen et al., *supra* note 6, at 773–74; James P. Muir et al., *Biomass Production of 'Alamo'*

The article concludes in Part IV with our observations of the biomass supply chain and recommendations for future research, including governance considerations and the ability of sustainability standards to lower transaction costs.

II.
THEORETICAL APPROACHES TO BIOMASS CONTRACT DESIGN

Contract theorists have devoted considerable literature to determining which organizational structure is most likely or appropriate for the developing biomass industry. Scholars have placed particular emphasis on complete vertical integration, commodity market models, cooperative structures, and vertical coordination.[13] For reasons detailed below, we assume a

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Switchgrass in Response to Nitrogen, Phosphorus, and Row Spacing, 93 AGRONOMY J. 896, 896 (2001). A vigorous plant with a C_4 photosynthetic pathway, switchgrass has been reported to yield up to 34.6 t DM/ha (14 t DM/acre), although yields can greatly vary. *See generally* Lewandowski et al., *The Development and Current Status of Perennial Rhizomatous Grasses as Energy Crops in the US and Europe,* 25 BIOMASS & BIOENERGY 335 (2003). The production life-cycle of switchgrass can last longer than ten years. John H. Fike et al., *Long-term Yield Potential of Switchgrass-for-biofuel Systems*, 30 BIOMASS & BIOENERGY 198, 205 (2006).

Miscanthus is a perennial C_4 grass that originated in the tropical and subtropical regions of Southeast Asia. Although many varieties exist, the variety that has received the most attention as an energy crop is *Miscanthus x giganteus*. Emily A. Heaton et al., *Miscanthus for Renewable Energy Generation: European Union Experience and Projections for Illinois,* 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 433, 440-441 (2004). This triploid hybrid is naturally sterile, does not produce viable seeds, and is propagated by dividing and planting rhizomes. *Id.* at 441. Growth generally begins from crowns in the spring (e.g., April, in Illinois), and is halted by flowering of the plant, or by frost, which kills the above-ground parts of the plant. L. Ercoli et al., *Effect of Irrigation and Nitrogen Fertilization on Biomass Yield and Efficiency of Energy Use in Crop Production of Miscanthus*, 63 FIELD CROPS RES. 3, 3 (1999). The plant can grow to 3-4 meters in height (9-15 feet). Heaton et al., *supra*, at 442. While yields may vary significantly, yields have been reported of 25 to 35 t ha^{-1} $year^{-1}$. Ercoli et al., *supra*, at 3. As the plant senesces in the fall (e.g., September to November in Illinois), the nutrients and carbohydrates are transferred down to the rhizomes and stored in the rhizomes during the winter. In the spring, the nutrients are mobilized to support rapid growth. Ercoli et al., *supra*, at 3. The life-cycle of the plant can extend longer than fifteen years. *Id.* at 4.

[13] *See generally* Heather Youngs & Caroline Taylor, *Biomass Supply Chains for a Bioenergy Future,* January/February 2011 RESOURCE 22 (2011); Mark

vertically coordinated industry structure.

No commodity markets currently exist for bioenergy crops. Experience tells us that spot markets traditionally fail to develop due to inadequate competition and price information, producer unwillingness to invest in land and production assets, and inadequate reflection of consumer preferences for product attributes in prices.[14] All these factors characterize the current state of the biomass industry. Although proposals to develop energy crop commodity markets do exist,[15] the current chicken-versus-egg problem hinders any significant progress. More specifically, biomass conversion facilities are unwilling to engage in substantial capital investment absent a stable source of raw material (i.e., biomass), while farmers remain skeptical about converting otherwise profitable and productive land resources to dedicated bioenergy crop production in the absence of a reliable (and at least equally profitable) market for their products. As spot markets for biomass commodities are unlikely to emerge until the industry is much more well-established, we concur with Altman and Johnson that current structural constraints make it likely that the bioenergy industry must be vertically coordinated in its early stages.[16]

Downing et al., *Development of New Generation Cooperatives in Agriculture for Renewable Energy Research, Development, and Demonstration Projects,* 28 BIOMASS & BIOENERGY 425 (2005) (discussing cooperatives); Ira J. Altman et al., *Applying Transaction Cost Economics: A Note on Biomass Supply Chains,* 25 J. AGRIBUSINESS 107 (2007) (explaining vertical coordination and vertical integration); CAROLINE TAYLOR & HEATHER YOUNGS, ENERGY BIOSCIENCES INST., EBI SCENARIO SERIES: MISCANTHUS X GIGANTEUS TO ETHANOL VIA DUAL FERMENTATION CURRENT TO NEAR-TERM TECHNOLOGY, EBI-BAT-S1, 6 (2009) (describing this model as a "diverse grower network.").

[14] JAMES MACDONALD ET AL., ECON. RES. SERV., U.S. DEP'T OF AGRIC. ECON. REP. NO. 837, CONTRACTS, MARKETS, AND PRICES: ORGANIZING THE PRODUCTION AND USE OF AGRICULTURAL COMMODITIES, 24–25 (2004).

[15] *See, e.g.*, Aditya Pyasi et al., *Biomass Forwards and Futures Market to Support Bioenergy Development,* IEEE Energy 2030 Conference, Art. No. 4781052, at 1 (2008).

[16] *See generally* Ira J. Altman & Thomas Johnson, *The Choice of Organizational Form as a Non-technical Barrier to Agro-Bioenergy Industry Development,* 32 BIOMASS & BIOENERGY 28 (2008); Ira J. Altman et al., Contracting for Biomass: Supply Chain Strategies for Renewable Energy, selected paper for presentation at the Southern Agricultural Econ. Ass'n Annual Meetings, Mobile, Alabama, Feb. 3rd-6th, 2007 (2006), *available at* http://

Although a few large-scale, purely vertically integrated models have arisen,[17] these models may have limited feasibility, particularly in areas such as the Midwest. By "vertical integration," we refer to industry structures where a party (either a producer cooperative or end-user) owns and operates all levels of the value chain. While initial pilot-scale projects may utilize successfully this type of wholly integrated structure, other financial, management, and environmental constraints may limit end-users' ability to vertically integrate sufficient land and production resources to supply large-scale bio-refineries over the medium- and long-term. Complete vertical integration seems more feasible when end-users are able to secure large contiguous tracts of land from a few large landowners. Particularly in the productive Midwest Corn Belt region, high agricultural land values may constrain energy crop production to "marginal" lands, creating the need for thousands of smaller tracts of farm land owned and operated by a diffuse set of landowners and producers. Moreover, vertical integration of sufficient land and production resources requires enormous start-up capital, which may also prove prohibitive for all but the most capital-rich end-users (e.g., petroleum companies) in a fledgling bioenergy industry.

As the industry evolves, a hybrid structure is likely to emerge, in which end-users closely cooperate with producers through long-term contracting, rather than as direct owners or operators of biomass farms. We term this a "vertically coordinated" industry model.[18] A vertically *coordinated* model presents several benefits over a vertically *integrated* system used in other industries dependent on vast quantities of raw materials, such as steel or petroleum products.[19] For example, a vertically

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ageconsearch.umn.edu/bitstream/34907/1/sp07al01.pdf.

[17] *See, e.g.*, *Vercipia: Accelerating the Development of Better, More Sustainable Biofuels*, VERCIPIA.COM, http://www.vercipia.com (last visited Apr. 9, 2013) (the home page of Vercipia Biofuels, a vertically integrated biofuels structure currently being developed by BP).

[18] *See* Taylor & Youngs, *supra* note 13, at 22.

[19] S.R. Dennison, *Vertical Integration and the Iron and Steel Industry*, 49 ECON. J. 244, 244 (1939) (describing integration in the steel industry); FED. TRADE COMM'N, GASOLINE PRICE CHANGES: THE DYNAMIC OF SUPPLY, DEMAND,

coordinated system does not disturb traditional agricultural practices or rural social structures that would result from transferring land and resource control to large energy companies. To the contrary, a vertically coordinated system that employs a variety of production contracts comports with recent trends in other agricultural sectors.[20] This model also permits a greater number of producers to participate by increasing contracting opportunities, and allows greater management flexibility for producers. Vertical coordination also facilitates biomass production on more marginal lands, which increases economic feasibility in areas with relatively high farmland values such as the Midwest. Finally, a vertically coordinated model is compatible with existing cooperative business structures, thereby easing the long-term assimilation of producer cooperatives into the biomass supply chain.[21]

Myriad contract theories can inform the transition to a vertically coordinated supply chain model, ranging from consideration of the social compatibility between actors, and risk- and cost-minimization behaviors. This article examines for the first time in scholarship the interactions and differences between these various theories in the context of building effective contractual relationships to facilitate the novel, emerging bio-economy. We first explore the influence of producers' social networks and trialability on contract design. We then turn to the importance of risk management tools already available in the traditional agricultural commodity space (e.g., crop insurance) to combat the uncertainty that can plague achievement of complete contracts, and highlight the importance of the parties' learning and experience as a risk management tool. Risk-sharing affects costs, and thus risk management theories overlap with the large body of economics literature on the role of cost in contract design. We thus incorporate economists' identification of adverse selection problems that

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AND COMPETITION at 124–25 (2005), *available at* http://www.ftc.gov/reports/gasprices05/050705gaspricesrpt.pdf.

[20] In 1969, production contracts accounted for 12% of the total value of U.S. agricultural production. MACDONALD ET AL., *supra* note 14, at 11. By 1991, this rose to 28% of total value and climbed to 36% in 2003. *Id.*

[21] *See generally* Mark Downing et al., *supra* note 13.

stem from information asymmetry and moral hazards into potential contract-based solutions, such as rationing, screening, signaling, and auctioning, as well as measurement and monitoring strategies. But, these theories assume that parties are able and willing to write complete contracts, or contracts that specify each party's obligations for possible contingencies. The section concludes by explaining why this is not always the case.

A. *The Socio-Compatibility Perspective*

While variations of the risk- and cost-minimizing perspectives are traditionally recognized in contract theory literature,[22] scholars rarely apply sociological perspectives directly to contract theory.[23] Scholarship should not underestimate, however, the influence of rural community norms and the learning styles of farmers who potentially will produce biomass.[24] The legal profession should therefore explore the ability of contracts to ameliorate the range of societal pressures that inhibit contract formation and execution.

Sociological research has identified several factors that determine farmers' willingness to adopt new technologies, as well as techniques to encourage innovation adoption.[25] This

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[22] *See, e.g.*, MACDONALD ET AL., *supra* note 14, at 25–29.

[23] *But see, e.g.*, Steven Wolf et al., *Policing Mechanisms in Agricultural Contracts*, 66 RURAL SOC. 359 (2001); Mark C. Suchman, *The Contract as Social Artifact*, 37 LAW & SOC'Y REV. 91 (2003).

[24] Margarita Velandia et al., *Intent to Continue Growing Switchgrass as a Dedicated Energy Crop: A Survey of Switchgrass Producers in East Tennessee,* 15 EUR. J. SOC. SCI. 299, 301 (2010) ("A full understanding of farmers' behavior towards switchgrass production implies not only the understanding of the economic motives behind farmers' intentions to continue growing dedicated energy crops (i.e., realized profits from biomass production), but the understanding of individual beliefs and social values behind the intentions to continue growing switchgrass as a dedicated energy crop.").

[25] Often this research has been applied to the adoption of conservation practices. *See generally* D.J. Pannell et al., *Understanding and Promoting Adoption of Conservation Practices by Rural Landholders,* 46 AUSTL. J. EXPERIMENTAL AGRIC. 1407 (2006); *see also* Michele Marra et al., *The Economics of Risk, Uncertainty and Learning in the Adoption of New Agricultural Technologies: Where Are We on the Learning Curve?*, 75 AGRIC. SYS. 215 (2003).

framework draws largely from the work of Professor Pannell, which summarizes decades of innovation adoption research through an interdisciplinary perspective.[26] According to Pannell, technology adoption research accedes that producers' willingness to adopt depends on their "subjective perceptions or expectations rather than objective truth" that the technology will help them to better achieve their goals.[27] Pannell further divides producer perceptions into three sets of issues: (1) characteristics of producers within their social environment; (2) technology attributes; and, (3) the process of learning and experience.[28]

Adoption is often a social process as producers interact with others to obtain and evaluate information.[29] The more complex and serious the consequences of the decision, the more producers seek information and social interaction.[30] Producers will look to those they perceive as trustworthy, credible, and possessing expertise, such as other farmers, researchers, and university extension agents.[31] Farmers process information according to their numerous and varied individual goals, as well as their familial and social network. We address in subsequent sections the purely economic goals of wealth and financial security.[32] Non-economic goals, however, impact greatly technology adoption.[33] Pannell lists several categories of non-economic factors, such as environmental protection and enhancement; social approval and acceptance; personal integrity and ethical standards; and balance of work and lifestyle.[34] As farmers

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[26] *See generally* Pannell et al., *supra* note 25.

[27] *Id.* at 1408.

[28] *Id.*

[29] *Id.* at 1410.

[30] Duncan Knowler & Ben Bradshaw, *Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research*, 32 FOOD POL'Y 25, 36 (2007).

[31] Maria B. Villamil et al., *Potential Miscanthus' Adoption in Illinois: Information Needs and Preferred Information Channels*, 32 BIOMASS & BIOENERGY 1338, 1339 (2008).

[32] *See, e.g.*, John Saltiel et al., *Adoption of Sustainable Agricultural Practices: Diffusion, Farm Structure, and Profitability*, 59 RURAL SOC. 333, 344 (1994); Marra et al., *supra* note 25, at 216–17.

[33] *See id.* at 221.

[34] Pannell et al., *supra* note 25, at 1410.

increasingly rely on social networks for information, technology adoption will more likely impact these variables. As the adoption process progresses, "social commitment and support will help maintain confidence in the uncertain stages of field testing and early adoption. Peer expectations of continued commitment or personal support and encouragement will reinforce commitment and provide a buffer against setbacks."[35]

In sum, these non-economic social constructs can increase the likelihood of contract formation and performance. And, because the process of technology adoption is dependent on the producers' social environment, maintenance of these social considerations should be taken into account in contract design.[36] Specific factors that aid in technology adoption in the rural context include: relative strength of social networks and local organization; proximity to other adopters and sources of information; history of respectful relationships between adopters and innovation advocates; education; promotion and marketing programs by the government (including land grant universities); and the private sector.[37] A national-level biomass production trade organization, along with local chapters, could increase social networking opportunities and identify potential peers for farmers seeking and processing information on conversion to biomass production. For example, the Illinois Biomass Working Group provides a collaborative network and educational opportunities for farmers considering biomass production in Central Illinois,[38] while the Council on Sustainable Biomass Production, a private standards development initiative, links farmers with industry experts to explore sustainable production methods for biomass.[39] As rural

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[35] *Id.* at 1411 (2006) (citing M. JANIS & L. MANN, DECISION MAKING: A PSYCHOLOGICAL ANALYSIS OF CONFLICT, CHOICE AND COMMITMENT (U.S. Free Press 1977)).

[36] *Id.* at 1411.

[37] *Id.* at 1412.

[38] ILLINOIS BIOMASS WORKING GROUP, http://www.illinoisbiomass.org/ (last visited Apr. 10, 2013).

[39] COUNCIL ON SUSTAINABLE BIOMASS PRODUCTION, http://www.csbp.org (last visited Apr. 10, 2013) (discussing field testing task force). In 2010, the CSBP began field testing its standard to ensure that it is "feasible, auditable, sufficient to protect important environmental and social values, and consistent with current science." CSBP, DRAFT PROVISIONAL STANDARD FOR SUSTAINABLE

communities have greater access and familiarity to web-based sources of information and social networks,[40] the importance of geographic proximity may decline in favor of general ease of information access—with Facebook and email replacing the coffee shop as the primary location for community information sharing.

Social networks, while significant, are not determinative, and, as may be expected, specific characteristics of the actual innovation also heavily influence the adoption of technology. Relative advantage, defined as "the degree to which an innovation is perceived as being better than the idea [or practice] it supersedes,"[41] is one key characteristic. An innovation's cost, risk, and profitability relative to current practices are major contributors to an innovation's relative advantage. But in addition to economic factors, the literature identifies several non-economic attributes with particular relevance to technology adoption in the sociological context.[42] These include non-economic adjustment costs; compatibility with a landholder's existing set of technologies, practices, and resources; government policies affecting the innovation, such as mandates or incentives to adopt or otherwise alter practices; compatibility of a practice with existing beliefs, values, and family lifestyle; self-image and brand loyalty; and the perceived environmental credibility of the practice.[43]

How much these factors influence technology adoption will again depend on the goals of the producer, and the social environment discussed previously. In this respect, the practical application of the concept of relative advantage is rather elementary: the greater the contracting parties can align the innovation adoption process to the non-economic goals of the

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PRODUCTION OF AGRICULTURAL BIOMASS 7–8 (2011), *available at* http://www.fao.org/bioenergy/28185-0c80b63a4db091a00b2e1cb187f714e73.pdf.

[40] *See* PETER STENBERG ET AL., ECON. RES. SERV., U.S. DEP'T OF AGRIC. ECON. REP. NO. 78, BROADBAND INTERNET'S VALUE FOR RURAL AMERICA (2009), *available at* http://www.ers.usda.gov/publications/err78/err78.pdf.

[41] Pannell, *supra* note 25, at 1413 (citing E.M. ROGERS, DIFFUSION OF INNOVATIONS 229 (5th ed. 2003)).

[42] *Id.* at 1413.

[43] *Id.* at 1414-15.

producer, the greater the innovation's relative advantage. Where the goals cannot be aligned, additional incentives may be required as compensation. As a step toward aligning these goals, recent efforts to develop sustainability certification schemes for biomass production (e.g., Council on Sustainable Biomass Production, Roundtable for Sustainable Biomass) seek to incorporate many of these social considerations into certification metrics, thereby creating a level playing field across biomass production markets.

A second innovation characteristic—trialibility—refers to how easily an innovation can be sampled in a small quantity or with low initial cost. Relative trialibility includes not only the ease of establishing a trial, but also the ability to learn from the endeavor.[44] Risk and uncertainty are decreased through trialibility in two ways: providing the producer the opportunity to gain skills in relation to the innovation, and allowing small-scale adoption to avoid risks of large-scale loss due to inexperience or failure of the innovation.[45] Several factors improve an innovation's trialibility, including possessing characteristics of divisibility and observability, as well as trials that are indicative of long-term performance. On the other hand, innovation complexity, trials with long time-lags, high up-front capital costs, and potential hazards provide significant barriers to trialibility. As with knowledge and learning, a trial experience minimizes uncertainty and increases the probability that the potential adopter will make correct decisions regarding whether and how to accept and implement the novel technology.[46]

A corollary to trialibility may be the presence of a certification regime, such as sustainability certification. The certification process may replace some aspects of trialibility as the communication mechanism between the sustainability standard certifier and producer provides a similar opportunity to gain skills related to the innovation and embark on steps to adoption without requiring an irrevocable commitment. The following section more thoroughly discusses the risk-minimization aspects

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[44] *Id.* at 1414, 1416-17.

[45] *Id.*

[46] *Id.* at 1416.

of trialibility, as well as the role learning and experience from the sociological compatibility perspective plays within the risk-minimization theory of contract design.

B. *The Risk-Minimizing Perspective*

Risk is inherent in all farming operations,[47] and successful producers expend considerable effort to manage negative risk exposure.[48] As one of the largest factors hindering producer participation in the biomass industry,[49] farmers must have adequate means to address and minimize risk prior to market entry. The main categories of producer risk traditionally include yield/production, price, institutional, human/personal, and financial.[50] Weather and technology are the primary components of yield risk.[51] Price risk refers to uncertainty in input and output prices, and institutional risk arises from changes in agricultural policies (e.g., price supports, ethanol mandates) and regulations (e.g., watershed protection, odor or dust minimization).[52] Personal risks include the risk of producer injury or death.[53] Farmers also face asset risk, the chance of loss of equipment, and contracting risk, which includes the threat of opportunistic behavior of contracting parties.[54] Financial risk includes the business risks of obtaining and financing capital.[55]

Contracting is a commonly accepted tool in mitigating and

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[47] ALAN MILLER ET AL., DEP'T OF AGRIC. ECON., PURDUE UNIV., RISK MANAGEMENT FOR FARMERS (Staff Paper No. 04-11, 2004), *available at* http://future.aae.wisc.edu/publications/risk_management_for_farmers.pdf.

[48] Rolf Olsson, *Management for Success in Modern Agriculture*, 15 EUR. REV. AGRIC. ECON. 239, 239 (1988).

[49] James A. Larson, *Risk and Uncertainty at the Farm Level*, *in* RISK, INFRASTRUCTURE AND INDUSTRY EVOLUTION: PROCEEDINGS OF A CONFERENCE JUNE 24-25, 2008, IN BERKELEY, CALIFORNIA 42–43 (Burton C. English et al. eds. 2008).

[50] Joy Harwood et al., ECON. RES. SERV., U.S. DEP'T OF AGRIC., AGRIC. ECON. REP. NO. 774, MANAGING RISK IN FARMING: CONCEPTS, RESEARCH, AND ANALYSIS, 7 (1999).

[51] *Id.* at 5–7.

[52] *Id.* at 7.

[53] *Id.*

[54] *Id.*

[55] *Id.*

sharing risk, and is a frequent topic in economic scholarship.[56] Before discussing risk-sharing in the context of formal economic contract theory, however, this article explores two other risk management tools: learning and experience, and traditional agricultural risk management tools.

High risk is not a new phenomenon for agricultural producers,[57] but the difference for the producer in the biomass industry is that the traditional agricultural risk management tools are either unavailable or significantly diminished in this novel production milieu. Recall that an important principle from the Sociological-Compatibility perspective is that producers feel comfortable and familiar with using existing agricultural structures and practices.[58] Therefore, the authors' critique of the Risk-Minimization perspective begins by describing traditional agricultural management tools and their limits in the biomass context, with the goal of identifying opportunities to resurrect these traditional tools through contracting strategies.

1. The Unavailability and Limits of Traditional Agricultural Risk Management Tools

Farmers rely on a variety of risk management tools in traditional commodity agricultural production. Commonly used options include crop insurance, commodity market strategies, diversification, financial management, leasing, and adjusting cultural practices.[59] Unfortunately, however, all these tools have

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[56] *See, e.g.*, MACDONALD ET AL., *supra* note 14, at 25-26; Brent Hueth & David A. Hennessy, *Contracts and Risk in Agriculture: Conceptual and Empirical Foundations,* Prepared for presentation at the SER-IEG-31 meetings on "A Comprehensive Assessment of the Role of Risk in Agriculture," Gulf Shores, AL, March 22-24, 2001, 1–6 (Nov. 2001), *available at* http://www.aae.wisc.edu/hueth/Papers/foundations.pdf; John H. Barton, *The Economic Basis of Damages for Breach of Contract*, 1 J. LEGAL STUD. 277, 278 (1972) (describing a contract as eliminating the risk of unfavorable price changes in the market).

[57] *See* HARWOOD ET AL., *supra* note 50, at 1.

[58] *See supra* notes 22–46 and accompanying text.

[59] *See* MACDONALD ET AL., *supra* note 14, at 32. Examples of cultural practices in the agricultural context include: farm location, crop rotation, soil quality management, sanitation, tillage practices, habitat manipulation/diversity, intercropping, and adjustment to planting and harvest dates. *See* Geoff Zehnder, *Cultural Practices for Managing Insect Pests*, EXTENSION, http://www.extension.org/pages/18909/cultural-practices-for-managing-insect-

limited availability in the current biomass production environment.

For example, the Federal Crop Insurance Act provides for the development of policies for dedicated energy crops, but no policies are available currently for *Miscanthus* or switchgrass—two promising bioenergy crops.[60] Insurance products exist for corn grain, but current policies do not take into account the production and harvest of corn stover for bioenergy purposes.[61] Similarly, commodity market strategies provide key risk management tools for producers to manage price risk, one of the larger risk exposures in agricultural production.[62] Farmers can use existing commodity and futures markets to practice certain risk management strategies, such as hedging, futures, and options contracts, and forward pricing.[63] As commodity markets do not exist for *Miscanthus*, switchgrass, or corn stover, biomass producers cannot take advantage of this important price risk management tool.

As a second strategy, producers often diversify operations to manage production and price risk.[64] Two types of diversification are common: enterprise diversification and geographic diversification.[65] Enterprise diversification involves participating in more than one activity, such as growing multiple types of crops or using multiple cultural practices.[66] Geographic

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pests (last updated Mar. 12, 2010).

[60] *See* RISK MGMT. AGENCY, U.S. DEP'T OF AGRIC., *Information Browser: County Crop Programs*, http://www.rma.usda.gov/data/cropprograms.html (last visited Apr. 10, 2013).

[61] Producers routinely use other forms of private insurance, such as property, health, and liability insurance, to transfer many kinds of asset risk, health risk, and liability risk. *See* HARWOOD ET AL., *supra* note 50, at 48–49. Producers, however, may have difficulty in acquiring insurance policies with riders for any novel risks created in the nascent biomass industry.

[62] *Id.* at 29.

[63] *See generally id.*, at 29–39. A full explanation of these marketing strategies is beyond the scope of this paper. For an overview of commodity market strategies, *see* Carl R. Zulauf & Scott H. Irwin, *Market Efficiency and Marketing to Enhance Income of Crop Producers*, 20 REV. AGRIC. ECON. 308 (1998).

[64] HARWOOD ET AL., *supra* note 50, at 14–17.

[65] *Id.*

[66] *Id.* at 14–16.

diversification refers to spreading crop production over several noncontiguous locations to reduce catastrophic weather risk.[67] Biomass contracts, as discussed below, however, may limit producer enterprise options for a variety of reasons. More importantly, the potentially high cost of transporting large quantities of biomass to the bioenergy conversion facility may further limit geographic diversification options.[68]

Asset leasing (e.g., land, equipment) provides farmers another traditional risk management strategy.[69] Leasing decreases financial risk by allowing producers to gain control over capital inputs without long-term payment commitments, and by increasing asset flexibility. However, this relatively simple strategy may have limited application in the biomass industry, as specialized equipment may be unavailable to lease or custom hire[70] due to the infancy of the industry. Landowners may be unwilling to rent land to a farmer seeking to grow novel crops with the attendant long-term contract that typifies many biomass supply arrangements. Financial flexibility and access to credit may face similar limitations if lenders perceive that producers are unable to adequately manage the relatively higher risk inherent in the nascent bioenergy industry.[71]

A final risk management strategy traditionally used by producers is adjusting cultural practices, including tillage

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[67] *Id.* at 17. Diversification incurs tradeoffs, however, as producers lose gains from specialization and incur greater capital costs. *Id.* at 15–16.

[68] Francis M. Epplin, *Cost to Produce and Deliver Switchgrass Biomass to an Ethanol-conversion Facility in the Southern Plains of the United States*, 11 BIOMASS & BIOENERGY 459, 465 (1996) (estimating the cost of delivering one dry ton of biomass).

[69] HARWOOD ET AL., *supra* note 50, at 46–48.

[70] Custom hiring refers to the practice of employing third-party independent contractors for individual farming activities, such as planting or harvesting. Furthermore, custom hiring contains inherent risks because the producer lacks control over the assets; producers are particularly susceptible to risks involved with activities that are dependent on critical timing, such as planting and harvest, as well as opportunistic behavior on behalf of the independent contractor. *Id.* at 48. *See also* W. Huisman & W.J. Kortleve, *Mechanization of Crop Establishment, Harvest, and Post-harvest Conservation of* Miscanthus sinensis *Giganteus*, 2 INDUS. CROPS & PRODUCTS 289 (1994) (discussing mechanization and production costs of *Miscanthus*).

[71] HARWOOD ET AL., *supra* note 50, at 46.

practices and input levels, to account for price and policy changes.[72] This simple strategy may be limited in the biomass industry in at least two ways. First, crop attribute requirements and cultural practice obligations incorporated in biomass contracts may limit farmers' ability to adjust methods. Second, the producers' relative unfamiliarity with novel energy crops may limit knowledge of alternative production practices.

Thus, many of the historical tools for farm risk management are largely diminished in the biomass context. This contributes to the high level of producer-perceived risk in the biomass industry and resulting reluctance to transition from commodity crop production to potentially more profitable dedicated bioenergy crops. But to the extent that biomass contracts between producer and end-user can recreate these traditional risk management tools, perceived risks may decline and facilitate adoption at lower cost.

2. Learning, Experience, and Risk Management

A second major tool in decreasing producer risk in the biomass context—learning and experience—arises from both rural sociology research on innovation adoption and economic risk-minimization scholarship. The learning and experience process is a critical method to reduce risk and uncertainty, thereby encouraging adoption.[73] The literature identifies the adoption of technology as a dynamic learning process, in which learning and experience decrease risk by reducing uncertainty, improving decision making, and enhancing skill.[74] As producers gain

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[72] *Id.* at 57–58. Tillage refers to the incorporation of plant residual material into the soil to serve as a nutrient for future crop production. In recent years, agronomists have attempted to modify tillage techniques to balance soil conservation with nutrient input. *See* R.R. Allmaras & R.H. Dowdy, *Conservation Tillage Systems and Their Adoption in the United States*, 5 SOIL & TILLAGE RES. 197 (1985). Typical off-farm inputs include fertilizer and pesticides—practices that require significant up-front costs—which farmers can manage on an as-needed basis. *See* Gary Schnitkey, *Crop Budgets, Illinois, 2012*, FARM BUSINESS MGMT. (Mar. 2012), *available at* http://farmdoc.illinois.edu/manage/2012_crop_budgets.pdf.

[73] Saltiel et al., *supra* note 32, at 344.

[74] Marra et al., *supra* note 25, at 224–27; Pannell et al., *supra* note 25, at 1408. As producers collect information and gain experience with technology, the

knowledge and experience with the innovation, skills improve in adapting the crop to particular agronomic and operational situations, and thus decrease the chance of failure.

This dynamic learning process includes several stages: awareness, non-trial evaluation, trial evaluation, adoption, and review/modification.[75] From these categories one can see that learning occurs throughout—before trialing via information collection and continuing through post-adoption in the form of adaption to new production information. While the learning process heavily depends on the trialibility of the innovation, learning and experience is much broader, and can be derived from more sources and methods than those that depend on the trialibility characteristics of the innovation. Certification systems, such as private sustainability standards, can provide key avenues of learning as potential adopters work with individual certifiers to implement innovative practices. University-based demonstration farms and extension outreach services also provide proxies for trialibility by sharing information in an open, collaborative environment.[76]

The implications of the learning/experience literature for designing biomass contracts are simple, but important. Because learning and experience is a major tool in reducing risk and uncertainty, contracts incorporating provisions to facilitate and

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producers' uncertainty decreases, and the accuracy of the information on which they are basing their decision improves. With more accurate information, the quality of their decision making improves, and the chance of making the wrong decision decreases. *See* Marra et al., *supra* note 25, at 226–27.

[75] Pannell et al., *supra* note 25, at 1408–09.

[76] For example, the Energy Biosciences Institute—a joint collaboration between the University of California, Berkeley; the University of Illinois at Urbana-Champaign; the Department of Energy's Lawrence Berkeley National Laboratory; and the international energy company BP, which funds the research—has a 320 acre energy farm, which facilitates the study of "information on yields, geographic variation and agronomic requirements of lignocellulosic feedstocks and tropical lignocellulosic/sugar feedstocks, and to identify agronomic procedures and feedstocks that will facilitate sustainable systems for the production of biofuels worldwide." Ul Voigt et al., *Feedstock Production/Agronomy Program,* ENERGY BIOSCIENCES INST., http://www.energybiosciencesinstitute.org/index.php?option=com_content&task=view&id=129&Itemid=2 (last visited Feb. 22, 2013). The Energy Farm at the University of Illinois at Urbana-Champaign hosts an annual field day where stakeholders and the public may tour the facilities and attend research presentations.

reward learning, both before and after the contract is signed, would provide a non-monetary, yet important incentive for farmer acceptance. Moreover, as the learning process continues beyond adoption, contracts that allow for information sharing between third parties, such as knowledge and experience with growing and harvesting biomass, would provide similar incentives. Unfortunately, at this stage of the industry, secrecy is often the norm in production contracts. This secrecy increases the perceived risk (and accompanying risk premium) for some potential adopters and warrants additional research on the benefits and costs of these non-disclosure terms in a developing industry.[77]

3. Economic Contract Theory and Risk-Sharing

The literature on formal economic contract theory generally focuses on two contract functions: risk-sharing and cost-minimization.[78] These two functions contain significant overlap and often conflict, in part because costs can be so broadly defined as to encompass all concepts of risk.[79] Many cost-minimizing principles and tools can be gleaned from the economic contract literature, discussed more fully in Part II.C. below. However, in this section we discuss aspects of economic contract theory to mitigate and share risk, and the tradeoff between minimizing risk and cost.

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[77] Interestingly, in response to a proliferation of non-disclosure clauses in agricultural production contracts in other contexts (e.g., hogs, poultry), some states have codified rules that allow farmers to share contract information with family members and legal/financial professionals. Stu Ellis, *Scared of Production Contracts? Some New State Laws are Leveling the Playing Field*, FARMGATEBLOG.COM (June 15, 2006, 5:02 PM) http://www.farmgateblog.com/article/165/scared-of-production-contracts-some-new-state-laws-are-leveling-the-playing (describing rules in Arkansas, Georgia, Illinois, Iowa, Kansas, Minnesota, and Wisconsin).

[78] MACDONALD ET AL., *supra* note 14, at 25–29; Hueth & Hennessy, *supra* note 56, at 1–6 (exemplifying a risk-sharing approach); DOUGLAS W. ALLEN & DEAN LUECK, THE NATURE OF THE FARM (2002) (exemplifying a strict transaction-cost approach).

[79] For example, the risk of opportunism leads to costs of underinvestment, and thus minimizing underinvestment costs can be equally perceived as minimizing the risk of opportunism.

Contracts can minimize both exogenous and endogenous[80] producer risks in two ways: eliminating risk, and transferring risk to another party. Exogenous risk arises from factors outside the parties' control, such as weather and policy changes. As such, parties to the contract cannot eliminate exogenous risk, but can transfer or share it amongst themselves. On the other hand, endogenous risk arises from the actions of the parties, such as opportunistic behavior and default. Accordingly, parties can minimize endogenous risk by controlling or incentivizing certain actions within the contract framework.

Although farmers usually bear exogenous production risk, some contracts for traditional agricultural commodities transfer this risk to the end-user.[81] For example, yield risk—a function of, among other things, weather—can be transferred completely to the end-user by contracting for a set amount of acreage production, rather than a fixed volume.[82] Parties also can eliminate price risk over the term of the contract by establishing constant unit prices or price floors and ceilings.[83]

Information asymmetry and incomplete contracts are two common sources of endogenous risks, which give rise to the risk of opportunistic behavior. To exemplify the endogenous risk-minimization function of contracts, consider the following classic example addressing moral hazard from the end-user's perspective. The risk of opportunism arising from moral hazard and adverse selection typically is addressed through the Principal-Agent Framework by providing incentives in the

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[80] The author's use of this terminology is meant in the generic sense, and not intended to relate this concept to any other research in which these terms may be used, such as finance and securities investment research.

[81] MACDONALD ET AL., *supra* note 14, at 25–29; *but see generally* ALLEN & LUECK, *supra* note 78, at 704 (arguing that the purpose of crop-share lease contracts is not risk-sharing).

[82] *See* James A. Larson et al., *Economic Analysis of the Conditions for Which Farmers Will Supply Biomass Feedstocks for Energy Production* 3–4 (Nov. 20, 2007), *available at* http://www.agmrc.org/media/cms/2007UTennProjDeliverable_9BDDFC4C2F4E5.pdf.

[83] All price risk is not transferred, however; only down-side price risk is transferred. Producers then lose the chance for higher profits if the price of biomass increases above the contract price, or if other substitute ventures become more profitable.

contracts to align the goals of the parties.[84] Suppose an end-user (the Principal) would offer a producer (the Agent) an acreage-based contract, where the producer delivers to the end-user whatever yield is produced off of a fixed number of acres, for a fixed price per acre. Because the producer's income does not depend on yield, the producer may act opportunistically, such as by applying less than the optimal amount of fertilizer to the crops. Information asymmetry is present because the farmer knows more about production practices than the end-user. Upon delivery, the end-user cannot determine if the lower than optimal yield was because of the lack of producer effort or from exogenous factors, such as poor weather, and thus cannot justify penalizing the farmer for a poor yield.

This is especially true with novel cropping systems, such as dedicated bioenergy crops, as there is neither a history of production/yield data nor comparable county average yields, such as those available for established commodities (e.g., corn, soybeans, cotton, etc.).[85] Thus, in order to decrease the risk of opportunism, the end-user must provide incentives to align the goals of the producer with those of the end-user. One such method would be to offer a payment structure dependent solely on yield, such as a set price per tonnage. The end-user could also modify the acreage contract and provide a bonus payment for achieving a higher yield. By incentivizing the producer to maximize yield, these strategies decrease the risk of opportunism for the end-user, but at the cost of transferring exogenous yield risk to the producer.

A key principle of economic contract theory and risk-sharing is that there is nearly always a tradeoff between risk and costs. The traditional agricultural management tools discussed in the prior section impose some costs (e.g., premiums for crop insurance, commissions for commodity market transactions,

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[84] *See infra* notes 95-127 and accompanying text; the Principal-Agent Framework will be discussed in detail in the cost-minimizing section.

[85] For example, the USDA National Agricultural Statistics Service compiles yield per harvested acre maps at the county level for twenty-five common commodity crops. *See* National Agricultural Statistics Service *Charts and Maps*, http://www.nass.usda.gov/Charts_and_Maps/Crops_County/index.asp (last visited Apr. 10, 2013).

rents for leasing equipment, loss of specialization resulting from diversification, interest expense for many financial strategies, and loss of the opportunity for favorable price movements when locked into fixed price contracts).[86] Gaining information and experience also is costly. Similarly, transferring exogenous risk through contracting will usually incur a risk-transfer premium, as the party assuming risk must be compensated.[87] This is identical in concept to insurance premiums for any traditional type of insurance, such as property or health insurance.

Minimizing endogenous risk also comes at a cost. Writing and enforcing more complete contracts is costly, and difficult to achieve, especially in novel markets. Incentive payments are problematic for both parties. The party creating the incentive (the Principal) incurs the costs of pay-for-performance incentives. The party accepting the incentive payment (the Agent) ends up assuming more risk, as is shown in the previous example. When the Agent is risk averse, the Agent will demand a risk premium to compensate for the additional risk created by the incentive payment. Bogetoft and Olesen explain this well:

> To provide incentives for unobservable actions [e.g., moral hazard problems], compensation to producers must be based on outcome. However, usually there is a stochastic relationship between the actions and the resulting output. This implies that output-based incentives will expose the producers to risk, because the output depends on factors outside the producer's control (e.g. weather). When the producers are risk-averse, this risk carries a risk premium. Hence, there is a trade-off between providing incentives and minimizing the cost of risk.[88]

In other words, tightening the Agent's incentives generally transfers some risk back to the Agent. Where the Agent is risk averse, the Principal must compensate the Agent for assuming

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[86] *See* MACDONALD ET AL., *supra* note 14, at 32.

[87] As biomass contracts are relatively new and lack default rules, the concept of "transferring" risk, which implies a starting point for negotiation, may not accurately describe the situation. Accordingly, a more precise term would be "allocating" risk.

[88] Peter Bogetoft & Henrik Ballebye Olesen, *Ten Rules of Thumb in Contract Design: Lessons from Danish Agriculture,* 29 EUR. REV. AGRIC. ECON. 185, 194 (2002).

the additional risk. Thus, as a general principle, risk-minimization is costly.

C. *The Cost-Minimizing Perspective*

The Cost-Minimizing Approach focuses on the third category of producer issues: cost concerns. The fields of economic contract theory and law and economics have elucidated a number of principles and tools that serve to minimize the costs to contracting parties. Although costs can be defined so broadly as to encompass both sociological concerns and risk, this paper uses the term to refer to two main sources of economic transaction costs: costs arising from information asymmetry and costs arising from incomplete contracts. Recall that these two sources also give rise to the risk of opportunism, as discussed in the prior section, which creates the overlap and tradeoff between cost- and risk-minimization.[89] Economic contract theory has recognized that a main (perhaps even primary) function of contracting is to minimize transaction costs, a principle originating from the Coase Theorem, and extensively expanded upon by other scholars, including Oliver Williamson and Oliver Hart.[90]

Potential biomass producers face transaction costs in the form of inefficiencies that arise from lack of coordination, holdup costs, and economic barriers that hinder market opportunities. The end-users face some of the most significant transaction costs in the biomass context; therefore, parts of the cost-minimization perspective are better understood and applied from the end-user's perspective. But, as discussed below, strategies to reduce transaction costs can have serious consequences for producers and thus reduce incentives to adopt the technologies essential for establishing a stable biomass supply chain.

1. Information Asymmetry Costs: Searching, Measuring,

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[89] *See supra* notes 78-88 and accompanying text.

[90] *See generally* R. H. Coase, *The Nature of the Firm*, 4 ECONOMICA (n.s.) 386 (1937); Oliver E. Williamson, *Transaction Cost Economics: The Governance of Contractual Relations,* 22 J.L. & ECON. 233 (1985); Oliver Hart & John Moore, *Property Rights and the Nature of the Firm*, 98 J. POL. ECON. 1119 (1990); Allen & Lueck, *supra* note 78.

Monitoring

Transaction costs arise when there are information asymmetries between two contracting parties.[91] The literature distinguishes between two types of information asymmetries: hidden information, and hidden action.[92] Hidden information, which creates adverse selection problems, gives rise to search costs of finding optimal contracting partners and their preferences.[93] Hidden action, which creates moral hazard problems, incurs a measurement cost of determining product quality and also incurs monitoring costs ensuring execution of all contract terms.[94]

a. *Information Asymmetry*

Economists traditionally model information asymmetry problems through the Principal-Agent Framework, where the uninformed Principal offers a contract to an informed Agent.[95] For example, a bio-refinery may offer a standard form contract to a number of producers, of whom the end-users know little or nothing about. While this model does not perfectly fit every structure of the biomass industry (e.g., where rigorous negotiation is possible), the Principal-Agent model remains useful in identifying and addressing information asymmetry issues.

Adverse selection problems arise during the negotiation of the contract when the Agent knows more about personal tolerances and preferences than the Principal knows or can observe.[96] For example, producers know their risk tolerance, opportunity cost, and minimum demand for compensation, whereas the end-user can only speculate as to an individual producer's

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[91] MACDONALD ET AL., *supra* note 14, at 26–27; Allen & Lueck, *supra* note 78, at 3–12.

[92] Paul J. Ferraro, *Asymmetric Information and Contract Design for Payments for Environmental Services,* 65 ECOLOGICAL ECON. 810, 811–12 (2008).

[93] *Id.*; MACDONALD ET AL., *supra* note 14, at 28.

[94] *Id.*; Ferraro, *supra* note 92, at 811–12.

[95] BERNARD SALANIÉ, THE ECONOMICS OF CONTRACTS: A PRIMER 5 (2d ed. 2005).

[96] Ferraro, *supra* note 92, at 811; SALANIÉ, *supra* note 95, at 11–28.

characteristics.[97] Producers can then "use this private information as market power to extract information rents" from end-users, by negotiating for a payment higher than the minimum that would be necessary for them to accept the contract.[98] For example, suppose there are two types of potential biomass producers, high-opportunity-cost producers and low-opportunity-cost producers. In order for the biomass end-user to incentivize the producers to participate, he will have to pay the high-cost producer a higher compensation than the low-cost producer to overcome his greater costs. However, when the end-user cannot observe the types of the producers, the low-cost producers have the opportunity and incentive to portray themselves in negotiation as high-cost producers to extract the additional rents necessary to attract high-cost producers. The result of the end-user's inability to distinguish between producers is higher total input supply costs. Economic contract theorists have discovered several methods to address adverse selection in the complete contract literature—the general goal is isolation strategies to encourage producers to reveal their types (i.e., cost profile) without incurring prohibitive information rents.[99]

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[97] Ferraro, *supra* note 92, at 811.

[98] *Id.*

[99] SALANIÉ, *supra* note 95, at 12. Based heavily on game theory, and particularly Mechanism Design, the complete contract theory literature can address information asymmetry problems. *Id.* at 11–18. In Mechanism Design, the Principal designs the rules (e.g., a contract) of a game of incomplete information (e.g., Bayesian Game) in which the object is to maximize the Principal's utility. The rules the Principal creates dictate the allocation of resources and utility of the parties for each possible "message" (or information) an Agent may report. *Id.* at 13–16. Mechanism Design relies on the Revelation Principle, which implies that a mechanism exists that can achieve the optimal outcome (e.g., Bayesian equilibrium) in which Agents truthfully reveal their information, because the Agents find it in their best interests to be truthful and not lie or act strategically. *Id.* at 16–18. Thus, as a consequence of the Revelation Principle, the Principal need only consider mechanisms that rely on Agents truthfully revealing their private information. The Principal (e.g., end-user) then designs mechanisms (e.g., production contracts) that optimize his utility, subject to constraints that arise from the characteristics of the Agents (e.g., producers). Incentive compatibility constraints ensure that the Agent is incentivized to choose to report his information truthfully over all other possible false messages (e.g., in adverse selection problems he will choose the contract

Within the Principal-Agent Framework, complete contract theory offers several possible solutions to adverse selection problems, including rationing, screening, signaling, and auctioning. These strategies constitute a set of tools for contracting parties to choose from in addressing adverse selection problems. To explain these concepts, consider again the example mentioned earlier in the "Principal-Agent" section.[100] The low-cost producer can produce a ton of biomass for $4/ton, plus an initial start-up cost of $100, up to a maximum of 100 tons (i.e., $\text{Cost} = 100 + 4t;\ t \leq 100$). The high-cost producer's cost per ton increases exponentially starting from $1/ton, and he also incurs $100 in start-up costs, up to a maximum of 100 tons (i.e., $\text{Cost} = 100 + t^2;\ t \leq 100$). To obtain the largest supply of biomass possible for the least cost, the end-user would seek to deal only with the low-cost producers. However, the end-user cannot limit engagement due to an inability to identify the low-cost producers and, more importantly, low-cost producers alone cannot satisfy total demand.[101] Therefore, the end-user must contract with both high and low-cost producers.

A relatively simple but problematic tool that Principals can use is termed *rationing*. Principals can use rationing to offer

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that is designed for producers of his type, rather than a contract designed for a producer with different type). *Id.* at 21–23. Individual rationality or participation constraints ensure that a producer will be incentivized to choose to report his information rather than not participate at all (e.g., in adverse selection problems he will prefer to sign the contract designed for producers of his type rather than not sign any contract). SALANÉ, *supra* note 95, at 21-23. Satisfying these constraints creates information rents for the Agents, which the Principal must pay to determine the Agents' types. The Agents with the least restrictive constraints (e.g., the most risk-neutral producers, or the producers with the lowest opportunity cost) will receive the highest information rents, while Agents with the most restrictive constraints (e.g., the most risk-averse producers or those with the highest opportunity costs) will receive no information rents, with a continuum in between. *Id.* at 26-27. This is because those with less restrictive constraints have the incentive to overstate the degree of their constraints to extract more compensation than would be necessary, but Agents with the highest constraints cannot profit from understating the magnitude of their constraints, as that would entitle them to less compensation. *Id.*

[100] Ferraro, *supra* note 92, at 812 (providing an example and explanation of screen strategy).

[101] *Id.* at 811.

contracts that are only feasible (i.e., satisfy the participation constraints) for the "better" (e.g., low-cost) producers.[102] In this way the end-user limits the amount of rents that the better producers can extract by claiming to be "worse" producers; because the end-user knows the worst producers cannot feasibly accept the contract, the producer cannot pretend to have their characteristics.[103] In our example, the end-user could offer contracts that would only be feasible for the low-cost producers and for a limited amount of high-cost production. For example, the contractor could offer $50/ton for biomass.[104] This scenario would create for the low-cost producer a profit of $2,700 producing a maximum of 100 tons, and would also make biomass production profitable for the high-cost producers up to a volume of 48 tons. The downside to this simple contract solution is that the number of producers that can participate is limited by rationing, both by decreasing the amount of supply an end-user can secure and by excluding potential high-cost producers from the biomass industry.[105] Also, the low-cost producers still extract relatively high information rents, as they would be incentivized by a much lower price (e.g., $5/ton would satisfy their participation constraints).

Economists have discovered a more complicated but perhaps more efficient strategy to address adverse selection—*screening*. With a screening strategy, the Principal offers a menu of contracts designed so that each type of producer will prefer the contract designed for his type; the producer cannot be better off by choosing a contract designed for another type.[106] In this way, end-users must design contracts not only to satisfy the producers' participation constraints, but also the producers' incentive compatibility constraints.[107] In our example above of just two types of producers, the end-user could offer two

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[102] Bogetoft & Olesen, *supra* note 88, at 196.

[103] *Id.*

[104] USDE, BILLION-TON Update, *supra* note 1, at xix (using a composite total price of $60 per dry ton, therefore $50 is a reasonable number).

[105] Bogetoft & Olesen, *supra* note 88, at 196.

[106] Ferraro, *supra* note 92, at 812.

[107] *Id.*

contracts: Contract 1 offering $2,601 for 50 tons of biomass, and Contract 2 offering $2,802 for 100 tons of biomass.[108] Offered the choice of these two contracts, the high-cost producer will choose Contract 1, as he will profit $1, and cannot profit from Contract 2, as his costs outweigh the compensation for 100 tons. The low-cost producer will always choose Contract 2. Although he could profit $2,301 under Contract 1, Contract 2 is designed to allow the low-cost producer to profit $2,302 and produce the maximum of 100 tons. This menu of contracts thus satisfies both producers' participation and compatibility constraints, and incentivizes both parties to reveal their types by their contract choice. Note that offering this menu of contracts results in higher production at lower costs than rationing ($36/ton for 150 tons compared to $50/ton for 148 tons). Note also that the end-user still must pay the low-cost producers' information rents (premiums above that which is necessary to satisfy their participation constraints) in order to incentivize acceptance of the contract designed for the low-cost producer. Screening thus decreases, but does not eliminate, the rents low-cost producers can extract from private information.[109] The amount of biomass that the high-cost producers can contract is also limited in order to make the high-cost contract less desirable for the low-cost producer.[110] Additionally, screening may limit producer participation.

Screening presents another significant challenge for Principals. In order to design a menu of contracts to satisfy both the participation constraints and incentive compatibility constraints of producers, the Principal must have detailed knowledge of the characteristics and distribution of each type of producer.[111] To the extent that an end-user's understanding of producers is lacking, especially in a fledgling industry such as energy biomass, the value and feasibility of screening may be limited severely.

A third method to address adverse selection is through the use

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[108] Obviously, the end-user would not allow a producer to contract for two 50-ton contracts to supply 100 tons.

[109] Ferraro, *supra* note 92, at 812.

[110] *Id.*

[111] *Id.*

of auctions, specifically procurement auctions.[112] In a procurement auction the buyer invites bids from suppliers for a specific contract.[113] In auctioning, the lower-cost producers can still extract information rents from the end-user, as they must only offer a price just below the next lowest bidder, a strategy called bid shading.[114] Therefore, they always offer a bid higher than their minimum bid, extracting the difference as information rent.[115] The lower-cost the producer, the higher the information rent they can extract, while the highest-cost producer again cannot extract any information rent.

While auctions again only minimize and do not eliminate information rents, auctions provide several advantages over other methods, such as screening or rationing.[116] In theory, auctions can reduce the information rents without limiting production (i.e., auctions create less distortion to supply).[117] For example, while rationing uses fixed prices and screening limits to decrease the attractiveness to low-cost producers, auctioning uses competitive bidding to achieve the same purpose.[118] Finally, auctions dispense with the need of the end-user to know the cost distribution of different types of producers, and reveal changes in this cost distribution over time.[119] On the other hand, auctions present some unique challenges. They require a critical mass of bidders to ensure competitive bidding, and create more

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[112] *See* SALANIÉ, *supra* note 95, at 65–73.

[113] Ferraro, *supra* note 92, at 813. Bids can be offered in a number of methods, including the English auction, where bids are lowered (for procurement auctions) or raised (for sales auctions) until only one bidder remains; the Dutch Auction, where the auctioneer quotes increasing bids (for procurement auctions) or decreasing bids (for sales auctions) until a bidder accepts a quote; and sealed-bid auctions, where bidders privately offer a single bid. In a first-price, sealed-bid auction, the most favorable bid is accepted as the purchase/sale price. In a second-price, sealed-bid auction, the second most favorable bid is accepted as the purchase/sale price, a method that may encourage bidders to reveal their true highest bid. SALANIÉ, *supra* note 95, at 66.

[114] *Id.* at 68.

[115] *Id.*

[116] Ferraro, *supra* note 92, at 813–14.

[117] *Id.* at 813.

[118] *Id.* at 813–14.

[119] *Id.*

uncertainty for the buyer (e.g., the end-user in a procurement auction), as they offer fewer predictions of producer responses.[120] In addition, auctions can be costly and complicated to design and administer.[121]

A final strategy to address adverse selection is *signaling*, where the informed party (e.g., the producer) acts first to reveal their private information to gain an advantage.[122] This strategy has direct implications for both Principals and Agents. In a simple form of signaling, the Principal gathers information on observable characteristics of producers that are correlated with opportunity cost or other hidden information variables.[123] Based on this information, the Principal can create minimum eligibility requirements for contracting.[124] However, to prevent low-cost producers from masquerading as high-cost producers, the observable characteristics must be costly to fake.[125] Also, information collection can be costly, and "the ability of this information to reduce information rents without distorting [production supply] will only be as good as the strength of the correlation between the characteristics and [producer types.]"[126]

Some producers, (e.g., high-cost producers) may also find it in their best interest to take the initiative to use signals to reveal their private information (e.g., their type).[127] End-users can increase supply while limiting the potential for information rents by contracting with high-cost producers that effectively signal their type. By requiring signals that are impossible or costly to mask (i.e., signals that are more costly for low-cost producers than high-cost producers, and thus more commonly used by high-cost producers), the end-user can obtain the added production from high-cost producers without the risk of paying increased information rents from low-cost producers masquerading as high-cost producers.

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[120] *Id.* at 814.

[121] *Id.*

[122] SALANIÉ, *supra* note 95, at 98.

[123] Ferraro, *supra* note 92, at 812–13.

[124] *Id.* at 813.

[125] *Id.*

[126] *Id.*

[127] *See* SALANIÉ, *supra* note 95, at 99–102.

b. *Moral Hazard*

While adverse selection problems arise during contract negotiation, moral hazard emerges after the contract is signed. Moral hazard exists where the Agent makes a decision that affects the utility of both the Agent and the Principal, the Principal can only observe the outcome of the decision, which is an imperfect indication of the action, and the action that the Agent would take to maximize his utility does not simultaneously maximize the utility of the Principal (i.e., the objectives of the parties differ).[128] Information asymmetry in this case again gives rise to opportunistic behavior on behalf of the informed party, as they may shirk their effort.[129] Literature from sociology and economic contract theory has developed several tools to address moral hazard problems. To model this problem, we offer a second simple example in which an end-user has contracted with a producer to produce and deliver biomass. Assume that a producer's yield depends on two variables: (1) his effort (e.g., application of fertilizer, management time, etc.), which is costly to the farmer; and (2) the weather. The end-user and producer have signed an acreage-based supply contract, where the farmer is to deliver the entire crop from 50 acres of land to the end-user for a fixed price per acre. This scenario gives rise to moral hazard, as the farmer has an incentive to slough off, a decision that conflicts with the interest of the end-user seeking to maximize yield from the land under production.

Perhaps the most powerful tool available to address moral hazard is incentive contracting, developed in complete contracts literature.[130] However, incentive contracting also creates the trade-off between risk and cost discussed earlier in the Risk-Minimizing Perspective.[131] The economic contract literature assumes that only the outcome of the Agent's decision is observable, and thus the Principal can only influence the choice the Agent makes by conditioning the Agent's utility on the

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[128] *Id.* at 119; Ferraro, *supra* note 92, at 811.

[129] Wolf et al., *supra* note 23, at 363.

[130] *See* SALANIÉ, *supra* note 95, at 119–60.

[131] *See supra* notes 78-88 and accompanying text; *See also* SALANIÉ, *supra* note 95, at 119–21.

outcome.[132] However, because the outcome (e.g., yield) is imperfectly correlated to the Agent's actions (e.g., effort) due to the variability of weather, basing the Agent's utility on outcome imposes risk for the Agent.

Once again using mechanism design, the Principal (e.g., end-user) must maximize his utility subject to the producer participation constraints and incentive compatibility constraints. The incentive compatibility constraints imply that the contract must provide enough incentive that the producer prefers to put forth effort. For example, the producer must profit more from applying fertilizer than from failing to apply it. In our example above, where the end-user can only observe yield, the end-user can only base incentives on yield. Because application of fertilizer positively correlates with yield (i.e., the probability of a high yield increases with application of fertilizer), the end-user could modify the contract to award a bonus for achieving a certain threshold of yield. If the end-user can renegotiate the current contract, he might desire a price-per-ton contract over an acreage contract, to tie the Agent's utility (compensation) to outcome (yield). The proposition is quite a simple one: the end-user will give the Agent a higher payment when the end-user can infer from the outcome that the Agent made a favorable decision, and vice versa.[133]

While both these solutions may satisfy incentive compatibility constraints by incentivizing the farmer to put forth effort, they also increase risk, which serves to tighten a producer's participation constraints. In order to incentivize the producer to accept the incentive contract, the end-user must also satisfy the producer's participation constraints. Participation constraints may include a host of factors, economic and non-economic,[134] and the producer's aversion to risk. Therefore, as risk is passed to the producer to satisfy incentive compatibility constraints, end-users must provide larger payments to satisfy the producer's participation constraints. The extra compensation that the Principal must pay is an information rent that arises from the

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[132] SALANIÉ, *supra* note 95, at 119.

[133] *Id.* at 128.

[134] *See supra* notes 22–46 and accompanying text.

asymmetric information between the parties.

Within this general theory, several important principles emerge. First, the smaller the expected difference between outcome of a favorable Agent action and an unfavorable one, the larger the incentive must be to motivate the Agent to act.[135] The reason is because it becomes more difficult to distinguish between the Agent's action and inaction.[136] Also, the optimal strength of incentives is dependent on several factors.[137] Second, the greater the value of any additional producer effort and the greater effect the incentive will have on the producer's behavior, the stronger the incentive should be.[138] Finally, the tradeoff between risk and incentive implies that weaker incentives should be given to more risk-averse producers.[139]

A more difficult problem arises, however, when a Principal has multiple objectives to maximize, and a producer's single action affects both objectives. When a producer's action supports one goal and opposes the other, incentive conflicts arise. The optimal balance will occur where the marginal benefit gained from incentivizing the producer to act to support one objective is equal to the marginal cost of the detriment to the conflicting objective.[140]

The value of incentive contracting is limited by more than the risk-cost tradeoff. Incentive contracts assume that outcome, and only outcome, is observable, and the Principal cannot gather additional information. Incentive contracts also assume that the Principal has no way to force the Agent to act. While in some scenarios these two assumptions hold true, the agricultural context provides unique opportunities to employ additional tools to manage incentives.

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[135] SALANIÉ, *supra* note 95, at 122.

[136] *Id.*

[137] Bogetoft & Olesen, *supra* note 88, at 194.

[138] *Id.*

[139] *Id.*

[140] *See* Robert E. Scott & George G. Triantis, *Incomplete Contracts and the Theory of Contract Design,* 56 CASE W. RES. L. REV. 187, 196 (2005) [hereinafter Scott & Triantis, *Incomplete Contracts*] (using this same principle to optimize the level of completeness, balancing the costs of additional contract completeness with the benefits of additional completeness).

Incentive contracts rely on "quality measurement," an observation limited by numerous factors, including the abovementioned inability to distinguish between quality arising from producer effort and quality arising from fortuitous circumstances (e.g., optimal weather conditions).[141] While yield is fairly easy to measure, other crop/production characteristics are more difficult to assess at delivery, such as moisture and ash content; carbon footprint; and other sustainability attributes (e.g., biodiversity, environmental stewardship). Large crop volumes, high costs of measurement technology, limited time, and logistical complexities further limit measurement ability.[142] Also, when measurements are controlled by a single party, the risk of opportunistic behavior arises from measurement errors or fraud.[143] Parties can address this risk, although at a cost, by employing third-party verification or allowing the other party to re-test.[144]

The literature has framed quality measurement problems in terms of *separability* and *programmability*. These terms refer to measurement characteristics of a transaction that reflect both the asymmetry of information and the costs of monitoring or verifying individual performance.[145] Separability refers to the "ability to evaluate an Agent's effort just by observing output," or "how much of the quality/quantity of the product is measurably attributable to the producer's management efforts[.]"[146] Programmability refers to "how closely output is tied to specific input decisions and observable management practices."[147]

Production processes that are highly separable (e.g., where

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[141] Wolf et al., *supra* note 23, at 369.

[142] *See id.* at 366.

[143] Bogetoft & Olesen, *supra* note 88, at 194.

[144] *Id.* For example, third-party auditing for certification to certain coffee production standards can range from $10,000 to $50,000. CONSUMERS INT'L, FROM BEAN TO CUP: HOW CONSUMER CHOICE IMPACTS UPON COFFEE PRODUCERS AND THE ENVIRONMENT 33–34 (2005), *available at* http://www.consumersinternational.org/media/306514/coffee%20report%20%28english%29.pdf.

[145] *See* Michael Sykuta & Joseph Parcell, *Contract Structure and Design in Identity-Preserved Soybean Production,* 25 REV. AGRIC. ECON. 332, 335 (2003).

[146] *Id.*

[147] *Id.*

outcome and effort are highly correlated) are appropriately addressed by incentive contracts, as the "allocation of value and risk will be efficient."[148] Utilizing incentive contracts for production processes that are not separable (e.g., outcome and effort is poorly correlated) creates weak incentives, increases producer risk, and also creates risk of opportunistic behavior by the producer.[149] If production is not separable but highly programmable, contracts can better address moral hazard by controlling the production process, depending on the cost of monitoring.[150] Sykuta and Parcell summarize this framework in terms of decision rights:

> If the quality of the output is highly separable . . . , then we would expect contracts to allocate more decision rights to the producer and provide rewards for wisely exercising those rights by linking compensation entirely to the quality . . . of the output. If separability is low but programmability is high, we would expect contracts that allocate more decision rights (in terms of production decisions) to the buyer in the form of task requirements. The producer would experience less autonomy.[151]

Thus one can see some limiting factors of incentive conflicts along with the necessity and value of the other methods of addressing moral hazard, which the authors discuss below.

One method to minimize opportunistic behavior arising from moral hazard is to increase control over production by specifying certain production practices (e.g., requiring the application of fertilizer and saving receipts). By writing into the contract specific task requirements, end-users turn unobservable actions into measurable criteria, and force producers to put forth the effort necessary to maximize end-user's utility.[152] In a sense, increasing control is an extreme form of monitoring, and could be an appropriate method to govern highly programmable production practices.[153]

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[148] *Id.*

[149] *Id.*

[150] *Id.* at 336.

[151] *See* Sykuta & Parcell, *supra* note 145, at 336.

[152] Wolf et al., *supra* note 23, at 367–68.

[153] *See supra* notes 145-51 and accompanying text.

Increasing control through more complete contracting has several drawbacks, however. First, end-users must incur the cost of writing and enforcing additional contract provisions, which may require additional monitoring and enforcement effort.[154] Decreased producer autonomy also requires compensation to overcome participation constraints and disallows potential gains from the producer's specialized knowledge and skills.[155] Two common examples of this type of control in the agricultural context are production contracts for poultry and hogs—both of which have engendered substantial farmer criticism due to perceptions of feeling trapped or intimidated by the contracts offered by the end-users of their products.[156]

An alternative method for the Principal to manage moral hazard is via monitoring.[157] One policing model that end-users could employ is the use of fieldmen, who periodically visit producers.[158] Creating a network of fieldmen yields a number of benefits. First, monitoring in this way increases the number of observable variables, by not only observing directly the production capabilities and practices of individual farmers, but also observing the production environment beyond the producer's control, such as weather and pest problems.[159] If the fieldman perceives opportunistic or suboptimal behavior on behalf of the producer, the fieldman can address the problem before damage occurs to the crop.[160] Although fieldmen may be perceived as "supervisors, spies, or adversaries," they can provide multiple benefits for producers, and farmers rarely have negative perceptions of these observers.[161] Moreover, fieldmen visits can provide a source of information and a familiar contact through

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[154] *See infra* notes 165-76 and accompanying text.

[155] Wolf et al., *supra* note 23, at 366.

[156] Christopher R. Kelley, *Agricultural Production Contracts: Drafting Considerations*, 18 HAMLINE L. REV. 397, 397 (1994).

[157] Wolf et al., *supra* note 23, at 368–69; Bogetoft & Olesen, *supra* note 88, at 192.

[158] Wolf et al., *supra* note 23, at 368–69; Bogetoft & Olesen, *supra* note 88, at 192.

[159] Wolf et al., *supra* note 23, at 368–69.

[160] *Id.*

[161] *Id.*

which producers could "negotiate contract terms, share technical information, estimate expected yields, and maintain a presence to ensure that the contract will be renewed[.]"[162] The use of fieldmen to monitor also allows for more flexibility over time, and creates "shared understanding of what constitutes standards of good professional practice[.]"[163] Thus, working in a cooperative spirit allows for expectation adjustments without costly negotiations or conflicts.[164] It must be mentioned, however, that although the fieldmen monitoring model has many benefits, several costs are involved, including the cost of hiring, training, and employing a staff of specialists (e.g., agronomists and ecologists) to serve in this role.

The previous discussion of adverse selection problems stemming from information asymmetry and the moral hazard problems associated with unobserved action offers several potential contract-based solutions, including rationing, screening, signaling, and auctioning, as well as measurement and monitoring strategies. But, much of the economic contract theory discussed above assumes that parties are able and willing to write "complete" contracts—contracts that specify each party's obligations for possible contingencies.[165] In practice, however, parties often are unable or unwilling to write and enforce complete contracts. Accordingly, in the following section, we introduce a second important transaction cost—contract incompleteness, and remedial strategies in the biomass supply chain context.

2. Incompleteness Costs: Asset Specificity, Property Rights, and Holdup

Consider the situation where the end-user and producer negotiate and execute *ex ante* a biomass production agreement that specifies a time and amount for delivery (e.g., "producer shall deliver 100 tons biomass"), but fails to specify a delivery location in the contract. Assume the end-user has two facilities,

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[162] *Id.*

[163] *Id.*

[164] Bogetoft & Olesen, *supra* note 88, at 197.

[165] Stéphane Saussier, *Transaction Costs and Contractual Incompleteness: The Case of Électricité de France*, 42 J. ECON. BEHAV. & ORG. 189, 190 (2000).

one ten miles from the producer and another, larger facility, one hundred miles from the producer. The lack of a specified delivery location is a source of incompleteness in the contract.

Contracts literature contains several theories for explaining why parties sign incomplete contracts. In extreme cases, complete contracts may not be necessary, such as in a transaction in an environment where all contingencies and variables are observable and verifiable, allowing perfect information to eliminate the risk of adverse selection or moral hazard.[166] But this is a rare situation.[167] Parties may end up signing incomplete contracts because of the bounded rationality of the parties, the presence of uncertainty in the transaction,[168] or the inability of the parties to objectively measure and evaluate relevant variables.[169]

A third explanation, closely related to the bounded rationality of the parties, is based on Williamson's transaction cost theory.[170] Williamson argues that complete contracts are unattainable because the transaction costs of writing and enforcing outweighs the benefits of obtaining perfection.[171] The marginal cost of additional completeness increases, while the marginal benefit of completeness decreases; thus, parties choose to write contracts with an optimal level of incompleteness where

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[166] *Id.*

[167] *See, e.g.*, SALANIÉ, *supra* note 95, at 193.

[168] Saussier, *supra* note 165, at 191; Oliver E. Williamson, *Assessing Contract*, J.L. ECON. & ORG. 177, 182 (1985). Bounded rationality assumes that actors are intendedly rational (i.e., are goal oriented and adaptive), but are limited by the information they possess and by their cognitive and emotional architecture. Bryan D. Jones, *Bounded Rationality*, 2 ANN. REV. POL. SCI. 297, 297–302 (1999).

[169] Saussier, *supra* note 165, at 191; Hart & Moore, *supra* note 90, at 1126–27; Eric Maskin & Jean Tirole, *Unforeseen Contingencies and Incomplete Contracts*, 66 REV. ECON. STUD. 83 (1999).

[170] Saussier, *supra* note 165, at 192–94.

[171] *Id.* at 192. Examples of contracting costs include writing the agreement, information acquisition, negotiation, monitoring, conflict resolution, and potential renegotiation when the parties are trapped in a bad contract. *Id.* at 193; Bogetoft & Olesen, *supra* note 88, at 200. The benefits of more complete contracts include a decreased risk of opportunism and savings on repeated negotiation costs, as the probability of an *ex post* renegotiation is lower. Saussier, *supra* note 165, at 193.

the marginal cost is equal to the marginal benefit of additional completeness.[172] As a bottom line, the general consensus is that contracts are *necessarily* incomplete; it is impossible to cover every possible contingency sufficiently well such that neither party will be able to take advantage of a loophole or ambiguity and act opportunistically.[173] Thus, incompleteness gives rise to the risk of *ex post* opportunistic behavior, which in turn creates transaction costs.[174]

In the complete contract literature, renegotiation serves as an *ex ante* constraint, incentivizing the parties to remain with the original contract,[175] but incompleteness creates the need for *ex post* renegotiation. Renegotiation can be a beneficial tool where a contingency occurs that leaves both parties worse off under the terms of the original contract; this flexibility allows the parties to adjust to changes in their environment.[176] This flexibility may even make incomplete contracts preferable to complete contracts in some scenarios. However, when certain transacting environments are present (e.g., asset specificity, below), renegotiation may be detrimental to one party, as it reduces commitment and may lead to strategic behavior.[177] Accordingly, a party may take advantage of any ambiguity or contingency not explicitly addressed in the contract to improve *ex post* payoff through renegotiation.[178]

When incompleteness exists, the future returns on a party's *ex ante* investment (and the risk of opportunistic behavior) will depend on the bargaining position of the party *ex post* (i.e.,

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[172] *Id.* at 193–94.

[173] Sykuta & Parcell, *supra* note 145, at 334; Williamson, *supra* note 168, at 181–82; Scott & Triantis, *Incomplete Contracts, supra* note 140, at 189–90; Robert E. Scott & George G. Triantis, *Anticipating Litigation in Contract Design*, 115 YALE L.J. 814, 816 (2006) [hereinafter Scott & Triantis, *Anticipating Litigation*].

[174] Ilya Segal, *Complexity and Renegotiation: A Foundation for Incomplete Contracts,* 66 REV. ECON. STUD. 57, 57 (1999); George W.J. Hendrikse & Cees P. Veerman, Marketing Co-operatives: An Incomplete Contracting Perspective, 52 J. AGRIC. ECON. 53, 54–55 (2001).

[175] SALANIÉ, *supra* note 95, at 194.

[176] *Id.* at 194–96; Bogetoft & Olesen, *supra* note 88, at 199.

[177] *See* Bogetoft & Olesen, *supra* note 88, at 199.

[178] Sykuta & Parcell, *supra* note 145, at 335; Segal, *supra* note 174, at 57.

during renegotiation).[179] Within incomplete contracts, economic contract literature has identified at least two factors in a transaction that influence a party's exposure to *ex post* opportunistic behavior: asset specificity[180] and allocation of property rights.[181] Both of these factors may create holdup, a form of opportunism.

Williamson defines the condition of asset specificity as "investments in which the full productive values are realized only in the context of an ongoing relation between the original parties to a transaction[;] such assets cannot be transferred to alternative uses or users without loss of productive value."[182] Legal scholars refer to specific assets as reliance investments.[183] Asset specificity creates a bilateral dependence (or bilateral monopoly) between the parties and a quasi-rent or "surplus over opportunity cost that increases the potential for opportunistic behavior."[184] Several types of asset specificity have been defined other than physical asset specificity, including "value-added specificity" (referring to added value in a product that is perceived only by the contracting party),[185] time specificity (e.g., where assets are perishable and timing is of the essence),[186] and site specificity (e.g., when transportation costs are high).[187]

When a party (e.g., seller) makes *ex ante* investments with high asset specificity, the seller is especially vulnerable in renegotiation, as the buyer knows that the next best value for the seller is substantially lower.[188] In renegotiation contexts, the

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[179] Hart & Moore, *supra* note 90, at 1122; Hendrikse & Veerman, *supra* note 174, at 54.

[180] *See* Williamson, *supra* note 90.

[181] *See* Hart & Moore, *supra* note 90; Patrick W. Schmitz, *The Hold-up Problem and Incomplete Contracts: A Survey of Recent Topics in Contract Theory,* 53 BULL. ECON. RES. 1, 1–2 (2001).

[182] *Id.* at 182.

[183] *Id.* at 181–84; Scott & Triantis, *Incomplete Contracts*, *supra* note 140, at 189.

[184] Sykuta & Parcell, *supra* note 145, at 335; Williamson, *supra* note 168, at 185.

[185] Sykuta & Parcell, *supra* note 145, at 336–37.

[186] *See* Hendrikse & Veerman, *supra* note 174, at 58.

[187] MACDONALD ET AL., *supra* note 14, at 26–29.

[188] Hendrikse & Veerman, *supra* note 174, at 55.

buyer will offer to pay only just above the next best offer, leaving the seller with no rents.[189] This opportunistic behavior on behalf of the buyer is called the "hold-up problem."[190] The party who considers *ex ante* whether or not to make an investment with high asset specificity can perceive the threat of holdup.[191] He realizes he has no incentive to invest as he will receive no rents, and therefore, will underinvest.[192] This inefficient level of investment creates transaction costs and barriers to entry.[193]

Again, consider our example of the biomass production contract. The biomass producer may choose *ex ante* to produce a crop of *Miscanthus*, and make a corresponding investment. Upon harvest (*ex post*) the parties must determine the delivery location. The harvested crop of *Miscanthus* has a high level of asset specificity; because the farmer has no alternative market for the energy crop, the next highest value is near zero. The biomass conversion facility understands this and, consequently, has significant bargaining power. The end-user may assert that delivery was meant to be at the larger, more efficient plant 100 miles away. The level of asset specificity puts the farmer in a weak *ex post* bargaining position, as he is dependent on the contract with the end-user and must satisfy the end-user to obtain revenue. Thus the farmer, even though he will incur higher transportation costs, would rather accept the added costs of transportation to a distant market than forego contract payments. In addition to this holdup, other producers who observe this scenario may refuse to invest, perceiving uncertainty and weaker incentives.[194]

Thus, one can see that asset specificity may create risk of opportunism and holdup. Several fields of literature have identified different strategies of addressing holdup, which we discuss below. However, the theoretical strategies—when placed

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[189] *Id.*

[190] For a more complete explanation, *see* Schmitz, *supra* note 181, at 1–17; Hendrikse & Veerman, *supra* note 174, at 55.

[191] Schmitz, *supra* note 181, at 5.

[192] *Id.*

[193] Hendrikse & Veerman, *supra* note 174, at 55.

[194] *See* MACDONALD ET AL., *supra* note 14, at 26–29 (providing additional agricultural examples of hold-up).

within the context of biomass production for renewable energy products—may conflict, requiring a balancing approach as well as careful analysis of specific issues to determine optimal strategies.

III.

CONSTRUCTING A FRAMEWORK FOR BIOMASS CONTRACTS

The preceding deconstruction of the sociological, risk-minimizing, and cost-minimizing perspectives yields several theoretical insights for an optimal biomass contracting framework, including key elements of contract design and opportunities for trade-offs in the negotiation process.

From the sociological perspective, sensitivity to non-economic factors tends to dominate decision making in the innovation context. The ability to maintain existing agricultural practices and social networks throughout the education, field trial, and commercial production stages minimizes farmer disincentives to enter into production contracts for novel biomass crops. Trialibility, information sharing, and education also have strong influences on the sociological-compatibility perspective of contracts. The risk-minimizing framework shares with the sociological perspective elements of information sharing, educational experience, and use of existing agricultural risk management tools, but also incorporates the concept of risk-incentive tradeoffs and minimization of common risk. Likewise, the cost-minimizing perspective incorporates aspects of the risk-incentive framework. But, cost-minimizing also includes unique attributes of controlling for moral hazards and adverse selection, as well as intentional design of incomplete contracts to incorporate renegotiation opportunities. Table 1, below, summarizes these results.

TABLE 1. AGGREGATE FRAMEWORK PERSPECTIVES OF THE AGRICULTURAL CONTRACT

Contract Attribute	Sociological Compatibility	Risk-Minimizing	Cost-Minimizing
Sensitive to Non-Economic Factors	X		
Existing Agricultural Practices	X	X	

and Risk Management Tools			
Educational Experience	X	X	
Information Sharing	X	X	
Trialibility	X		
Risk Incentive Tradeoff		X	X
Minimization of Common Risks		X	
Control for Moral Hazard			X
Control for Adverse Selection			X
Design for Contract Incompleteness			X

Accordingly, a trans-disciplinary approach to optimal biomass contract design would incorporate, to the extent possible, each of the contract attributes identified in Table 1. As discussed below, where perspectives overlap, contract design should be able to accommodate the differing frameworks, or at the least identify specific issues for negotiated bargaining. The more difficult proposition is when these principles are in conflict. For example, information sharing is a fundamental aspect of the sociological-compatibility perspective (and to a lesser extent in the risk-minimization framework), but is absent, or even discouraged from the cost-minimization perspective. The following section, therefore, analyzes the tools and implications of a Biomass Contracting Framework from a trans-disciplinary perspective.

A. *Trans-Disciplinary Approaches to Biomass Contracts*

Economic contract theory posits that parties to a contract must optimize the tradeoff between costs and risk, such that both parties' aversion to risk is equal to the additional cost of minimizing that risk.[195] As producers have different levels of risk tolerance, the appropriate amount of risk minimization will differ; risk adverse producers will be more costly to incentivize to participate than their risk neutral colleagues. Moreover,

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[195] Siddhartha Dasgupta, Thomas O. Knight & H. Alan Love, *Evolution of Agricultural Land Leasing Models: A Survey of the Literature*, 21 REV. AGRIC. ECON. 148, 149 (1999) (discussing risk allocation in the agricultural context).

identifying and addressing the risk tolerance of producers can be a key factor in adverse selection problems.

On the other hand, perhaps the most exacting lesson from the sociological literature is that producers have multiple and varied non-economic goals and barriers that must be addressed in order to facilitate adoption of energy crops.[196] What the sociology perspective implies, however, is that many of these non-economic goals cannot be adequately compensated by greater monetary incentives (the economic theory's risk vs. cost dichotomy); in order to overcome these constraints, contracting parties must incorporate other strategies to align the goals and incentives of the contract with non-economic considerations,[197] such as the impact on producer autonomy, lifestyle, current farming operation, and core values.[198]

At first glance, the absence of monetary incentives complements the cost-minimization perspective, but upon careful consideration it creates unique problems due to information asymmetry. Determining the underlying non-economic goals and barriers can be costly, especially for entities without extensive experience in the agricultural sector. For example, where a multinational oil company seeks entry to the biofuels market as the result of the RFS2 blending mandate, or where an electric utility previously reliant on coal and natural gas seeks a biomass supply for co-firing a power plant to comply with a state renewable portfolio standard, both actors may lack the institutional capacity to identify fundamental, non-economic barriers to farmer adoption.

The adverse selection problem discussed in the context of cost-minimization is made more complex as the end-user cannot confine information seeking activities to the differentiation of true high- and low-cost producers, as the end-user must also consider producers with divergent and variable non-economic

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[196] *See* Alissa M. Rossi & C. Clare Hinrichs, *Hope and Skepticism: Farmer and Local Community Views on the Socio-economic Benefits of Agricultural Bioenergy*, 35 BIOMASS & BIOENERGY 1418, 1420 (2011) (discussing non-economic goals in depth).

[197] Velandia et al., *supra* note 24, at 302.

[198] *See supra* notes 34–35 (discussing non-economic participation constraints).

goals not satisfied merely through financial means. As a result, theoretical methods of eliminating information asymmetry through rationing, screening, and auctions may not produce the desired results. On the other hand, the process of signaling[199] can enable end-users to identify particular non-economic barriers, along with the traditional high or low production cost structure. Moreover, cooperation and information sharing requirements embedded within a contract can enhance education and training elements, while also reducing information asymmetry.[200]

Cost-minimization and the sociological-compatibility perspectives thus are not inherently in conflict. The problem of information asymmetry and moral hazard is illustrative. As discussed above, one method for the Principal to manage moral hazard is via monitoring, and one potential model is the creation of a network of fieldmen to periodically visit producers.[201] Fieldmen can identify opportunistic or suboptimal behavior, while also providing a source of information among networked producers regarding not only technical production practices, but also financial information to lower future transaction costs.

The use of monitoring strategies (e.g., fieldmen) also implicates the risk-minimization perspective. Although incentives provide one method to allocate endogenous risk of opportunistic behavior,[202] incentive payments alone cannot differentiate between the endogenous risk of lack of producer effort from exogenous factors, such as poor weather. Moreover, incentive payments may not provide adequate compensation for the non-economic considerations described in the sociological-compatibility perspective. Alternative policing mechanisms, such as monitoring and collaboration through fieldmen, however, could address the endogenous moral hazard problems and minimize risk premiums.[203] Similarly, relative performance

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[199] *See supra* notes 122–26 and accompanying text (discussing the process of signaling).

[200] *See, e.g.,* Michael Allen, *Biomass Production Agreement*, Exhibit D (Nov. 4, 2010), http://energyindependence.wi.gov/docview.asp?docid=20757&locid=160.

[201] *See supra* notes 163–69 and accompanying text.

[202] Bogetoft & Olesen, *supra* note 88, at 194.

[203] *See supra* notes 157–64 and accompanying text.

contracts, such as tournament contracts, incorporate producer performance incentives relative to similar producers, rather than absolute measures that depend on common risks (e.g., weather).[204]

In addition to relative performance incentives and the use of fieldmen as means to address moral hazard problems without shifting additional, exogenous risk to producers,[205] pricing mechanisms can reallocate risk/minimize cost, while also facilitating access to traditional risk management strategies. The choice of pricing models offered in a biomass production contract can therefore have important implications for each of the three theoretical frameworks.

The simplest price provision offers a set price per unit of biomass throughout the duration of the contract. While this eliminates all down-side price risk from producers, it also forgoes the potential for higher gains should the value of biomass increase. An acreage contract that compensates the producer only by acres of production eliminates producer yield risk, but has analogous price risk consequences. Cost-plus pricing similarly eliminates all down-side price risk to producers by setting a fixed profit margin above the seasonably fluctuating cost of required inputs and shifts the long-range risk of rising input costs to the end-user. On the other hand, indexed pricing provisions, where the price of the biomass is tied to commodity prices or other benchmarks that fluctuate over time, account for the opportunity cost[206] of biomass production and enable use of

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[204] Bogetoft & Olesen, *supra* note 88, at 193.

[205] *Id.* Variations in common risk can be addressed further by grouping producers according to common characteristics, such as by geography for weather risk, and planting dates for other production risk. However, these groupings do not eliminate idiosyncratic risks of producers, such as disease outbreaks, equipment failures, etc. *Id.* Relative performance contracts also still transfer all yield risk to the end-user, as the end-user is not guaranteed a fixed amount of biomass.

[206] Other index pricing models may be based off of the producer's opportunity costs. *See, e.g.*, Allen, *supra* note 200, at Exhibit B, Schedule 2 (providing an example of an "Indexed Basis for Biomass" based on the opportunity cost of the producer). The price of the biomass is then tied to the substitute ventures of the producer, such as grain land cash rent, the price of corn or soybeans, pasture rent, Conservation Reserve Program payments, etc.

traditional agricultural risk management tools, such as the commodity market strategies discussed previously. The theory behind index pricing is to identify a correlation in pricing between biomass and established commodities. For example, the price of biomass may fluctuate proportionately to the price of corn, crude oil, or natural gas. Parties may develop creative indices to try to better match the price fluctuations of biomass, such as basing price on a theoretical "biomass index," which could consist of various percentages of commodity contracts.[207] The actual index price need not match the biomass price, but merely have proportionate price fluctuations. If this can be achieved, producers could employ market strategies (e.g., hedging, futures, options) in the respective commodities that compose the "biomass index" to protect their primary investments in biomass production.

Of course, producers will have heterogeneous preferences for pricing provisions based on their individual risk tolerances and marketing skills. Because of these differences, no single compensation provision will be optimal for every producer. Producers with low risk tolerance will likely prefer fixed pricing or profit margins, or guaranteed minimum revenue provisions. Producers with high risk tolerances may prefer indexed pricing arrangements to allow them the opportunity to gain from higher prices while employing market strategies to minimize downside risks.

As illustrated in the above discussion of pricing mechanisms, the potential contractual provisions embedded in a biomass contract are varied and fraught with complex tradeoffs unique to the agricultural context and further heightened due to the novelty of the bioenergy industry. Accordingly, the following section outlines many of the particular considerations of a biomass contract.

B. *Biomass Contracting Framework Considerations*

Table 1, above, is an aggregation and comparison of attributes

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[207] For example, an index could comprise three corn contracts, two crude oil contracts, a soybeans contract, and two natural gas contracts.

associated with contract theory frameworks. In Table 2, below, we propose a list of specialized contract provisions (columns) in relation to the identified contract attributes (rows). The result is a matrix framework for biomass contracting that incorporates the essential elements of the social compatibility, risk-minimization, and cost-minimization contract models.

Traditionally, biomass contracts have originated from end-users, and this model is likely to continue. The extent to which individual producers have the ability to negotiate provisions identified in Table 2 is questionable at this stage in the industry's development, and will likely vary by end-user. Notwithstanding the current state of the market and its "take-it-or-leave-it" biomass supply contracts, consideration of the issues and solutions discussed below can enhance participation and promote a more sustainable, stable biomass supply. And a stable, long-term biomass supply, at a low cost, is the single most important end-user objective.[208] The more secure the biomass production agreements, the more assured the end-users and their financiers are that the processing plant will be able to operate at a profitable rate and duration.[209]

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[208] Telephone Interview with Bill Belden, Senior Agricultural Specialist, Antares Group, Inc., and Kevin Comer, Senior Project Manager, Antares Group, (May 2011) (emphasizing the importance of a secure biomass supply for the end-user).

[209] *Id.* (emphasizing that the biomass production agreements are heavily influenced by the demand of the end-users' financers). In addition to a stable, low-cost supply, end-users also are concerned about particular attributes of the biomass crop. Energy content, an important crop attribute, refers to the amount of power or biofuel that can be extracted per unit of biomass (e.g., BTU content). Energy content will depend mainly on the type of crop, but production practices may also be able to influence this attribute. *See, e.g.*, Reed L. Hoskinson et al., *Engineering, Nutrient Removal, and Feedstock Conversion Evaluations of Four Corn Stover Harvest Scenarios,* 31 BIOMASS & BIOENERGY 126, 131–33 (2007) (discussing the ethanol conversion aspects of several different cutting heights of corn stover). End-users also generally desire low moisture content in crops; high moisture adds transportation, storage, and drying costs, and decreases the value per ton of biomass. *See id.* at 130. Mineral content of the biomass may also be a concern, as certain minerals may increase ash residues or even damage processing machinery. *See* Jan R. Pels et al., *Utilization of Ashes from Biomass Combustion and Gasification* 4 (14th Eur. Biomass Conference & Exhibition, 2005), *available at* http://worldcon.biz/download/ash_utilisation.pdf. The amount of foreign matter in the delivered crop is another significant attribute. Other

A discussion of strategies to integrate these considerations in a biomass contract follows.

TABLE 2. BIOMASS CONTRACT FRAMEWORK CONSIDERATIONS

Contract Provision	Sensitive to non-economic factors	Existing Agric. Practices and Risk Mgm't Tools	Educational Experience; Information Sharing & Trialibility	Risk Incentive Tradeoff	Min. Common Risks	Control for Moral Hazard	Control for Adverse Selection	Design for Incomplete Contract
Crop Selection	X	X	X	X				
Location Selection	X	X	X					
External Information Sharing	X	X	X					
Internal Information Sharing	X	X	X		X			X
Financing Options		X				X	X	
Yield Risk & Production Surplus				X	X	X		
Performance Incentives			X	X		X		
Intellectual Property	X					X		
Amortized Payments				X		X	X	
CRP Rollover Provisions			X	X				

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factors are also important, including the uniformity of the crop and the form in which the crop is delivered. The attributes that will be important and the degree to which they are important will depend heavily on the type of end-user (e.g., ethanol plant, combustion plant, etc.).

Leased-Land Considerations	X	X		X			X	
Crop Maintenance			X	X		X		
Pricing Mechanisms	X	X		X	X	X	X	X
Catastrophic Risk Management		X		X	X			
Environmental Liability				X	X			
Delivery & Storage	X	X	X	X	X	X		X
End-Product Specifications				X		X		X
Contract Duration, Renewability & Assignment	X	X	X			X	X	X

1. Production Diversity: Crop and Location Selection

Next to price, perhaps the most important aspect of the biomass agreement is the type of crop required. The producer's choice of crop—a complex interplay of issues discussed in Part II—will affect every part of the production process, from harvest and transportation, through conversion. Although end-users may seek to limit crop diversity due to the capacity of the biomass conversion technology, especially in ethanol production,[210] producers generally desire the freedom to choose the initial type of crop and, as preferences evolve, have the ability to adjust their choice.[211] Moreover, as described in the Risk-Minimizing Perspective, crop diversification is an important traditional risk

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[210] *See* Dylan Dodd & Isaac K.O. Cann, *Enzymatic Deconstruction of Xylan for Biofuel Production*, 1 GCB BIOENERGY 2, 12-13 (2009) (discussing variation in cell wall structure and optimized enzyme structure among plant species).

[211] Of course, there are significant transition costs for producers when switching between perennial and annual crop production.

management tool preserved by allowing crop choice flexibility.[212] The Sociological-Compatibility Perspective also instructs that contract provisions regarding the type of crop should take into account the non-economic goals of the producers (e.g., crops that will complement producers' lifestyle and traditional farming practices).[213] Accordingly, rather than mandating a specific crop choice, biomass contracts should specify delivery based on standardized measurements across multiple crop types. For example, contracts could base delivery requirements on "dry matter tons" or "British Thermal Unit (BTU) equivalents." Producers could then select their preferred level of diversity among a crop portfolio to decrease production and technological risk over the duration of the contract, while simultaneously accommodating for their individualized non-economic considerations.[214]

Moreover, genetic improvements during the duration of the contract may alter production returns associated with a particular energy crop. A non-specific production contract would minimize this technological risk and allow (or perhaps even incentivize) a shift to more efficient production options, providing a net societal gain in utility.[215] If end-users, perhaps due to technological restraints in conversion technologies, are unwilling to offer producers this flexibility at contract formation, fallback provisions could include a petition process to deliver alternative feedstocks in later years, as conversion technologies improve, without necessitating renegotiation of the base

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[212] *See supra* notes 64-68 and accompanying text.

[213] *See supra* notes 22-46 and accompanying text (discussing relative advantage and consideration of non-economic goals of the producer). More research, however, is needed to better understand producer beliefs and values. Maria B. Villamil, Anne Heinze Silvis & German A. Bollero, *Potential Miscanthus' Adoption in Illinois: Information Needs and Preferred Information Channels*, 32 BIOMASS & BIOENERGY 1338 (2008).

[214] For example, if pests, weeds, or a particularly dry year results in a poor *Miscanthus* yield, the diversified producer could harvest a certain amount of corn stover to meet production shortfalls.

[215] Much debate and research continues regarding the optimal energy crop for the Midwest, and this discussion is beyond the scope of this paper. *See* Madhu Khanna et al., *Supply of Cellulosic Biofuel Feedstocks and Regional Production Pattern*, 93 AM. J. AGRIC. ECON. 473 (2011).

contract.[216]

As discussed above, geographic diversification refers to spreading crop production over several noncontiguous locations to reduce catastrophic weather risk.[217] On the other hand, potentially exorbitant raw material transportation costs to the biomass conversion facility (and consideration of which party bears those costs) may limit geographic diversification options. Some government subsidy programs, such as BCAP, provide payments only to farms within a certain distance of the biomass conversion facility.[218] Accordingly, the ability to design contracts to accommodate geographic diversity may be limited by both cost and government rules. Nonetheless, conversion facilities seeking biomass suppliers should be aware of, and consider options within contracts to promote, or at least not unduly restrict, geographic diversification.

2. Education and Information Sharing

The Sociological-Compatibility and Risk-Minimizing Perspectives both teach the importance of learning, experience, and trialibility.[219] Because of the novelty and general lack of experience with energy crop production, education and trialing is critical for producers, and end-users can creatively support these considerations within both the negotiation and performance of the biomass supply contract.[220]

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[216] The provision should state that permission from the end-user cannot be unreasonably withheld. *See Locke v. Warner Bros., Inc.*, 57 Cal. App. 4th 354, 363 (1997) (holding that contracts that provide one party with discretionary power are nonetheless bound by the implied covenant of good faith and fair dealing).

[217] *See supra* notes 67–68.

[218] Biomass Crop Assistance Program, 7 C.F.R. § 1450 (2011) (limiting annual payments to producers within a particular "project area").

[219] *See supra* notes 22-46 and accompanying text.

[220] For example, during a negotiation period, end-users could offer internal seminars or workshops on energy crop production, as well as sponsor field trials and demonstrations in local areas. End-users, within the contract itself, could agree to provide ongoing opportunities for education and information sharing among growers as research and experience creates more information on energy crop production. These opportunities could come in the form of end-user sponsored seminars for producers, periodic newsletters, or fieldmen services. A commitment to the sharing of best practices not only increases social

From an external information perspective, a transparent, vertically coordinated system allows for the end-user to offer contracts to a large number of producers. Overly restrictive confidentiality clauses, however, may foreclose the ability of producers to make this decision in consultation with community-based peers and role models. Although end-users may have legitimate business reasons to prohibit disclosure of some contract terms, care should be taken to balance those needs with the underlying consideration that the beliefs and values of producers and their rural communities are important factors in the decision making process.[221] Toward this end, conversion facilities targeting "community leaders" and more innovative farmers can take advantage of the reputation of traditional first-movers in the community to encourage other participation.[222]

It is important to note that the current trialibility of most energy crops is often inherently poor, adding to the information uncertainty dynamics of contract negotiation.[223] Offering a

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acceptance, but facilitates increased long-run productivity across all growers. Venkatesh Viswanath & Fred D. Davis, *A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies*, 46 MGMT. SCI. 186, 187 (2000). As a weaker alternative to ensure information sharing, contracts may create "cooperation" provisions, requiring notification of any material change in circumstance that may affect performance of either party's obligations. *See, e.g.*, Allen, *supra* note 200.

[221] *See supra* notes 25-46 and accompanying text (discussing importance of social interactions, beliefs and values).

[222] Additional, non-contract strategies include broad biofuel advertising campaigns in rural areas to improve the reputation and public perception of bioenergy. To the extent that potential producers are concerned with any stigma attached to producing biofuels for a large company, contracts may provide for continued obligations to advertise and promote the benefits of the bioenergy industry, such as rural development and job creation, and environmental benefits. End-users may even experiment with promoting certain value-added characteristics, such as "home-grown fuel," "made in the U.S.A," and "green energy." *See generally* Diane Hite et al., *Consumer Willingness-to-Pay for Biopower: Results from Focus Groups*, 32 BIOMASS & BIOENERGY 11 (2008) (finding that many consumers are willing to pay a premium for biopower, implying that additional value can be gained through marketing strategies).

[223] For example, the divisibility of *Miscanthus* is relatively low; although a farmer could grow a small patch of the crop in a trial, the farmer will likely have little or no market for the crop without a contract. A production contract may or may not be available, but even if one is available, it is likely for large quantities and for the long-term. In addition, *Miscanthus* must be propagated by rhizomes

preliminary, short term contract with smaller quantity requirements, while providing equal access to quality information regarding research trials and production practices, will increase trialibility and reduce information uncertainty. As further incentive to engage producers in a step toward large-scale bioenergy crop production, these initial trial contracts could include, subject to performance measures, guaranteed renewability and quantity expansion terms

In sum, many of the risk-minimizing approaches to information asymmetry can complement non-economic goals and social interaction factors to make producers more comfortable in the decision to enter into a biomass supply contract. The principles from sociology are simple, but powerful. The stronger the relationship between the two parties, and the more value a party perceives in a favorable reputation, the less a party will be willing to hold up a contracting partner or otherwise act opportunistically.[224] Acting opportunistically, especially in relatively tight-knit rural communities, damages a Principal's reputation and may hinder the ability to contract with other potential Agents.[225] In general, biomass supply contracts should attempt to be cooperative rather than secretive, and account for the interaction and input of community engagement in the both negotiation and contract performance.

3. Biomass Production: Pricing, Yield Risk, Incentives, and Specifications

a. *Price*

As discussed above, contracts can minimize both exogenous and endogenous risks for both parties.[226] Transferring risk to the other party, however, usually results in a risk-transfer premium, while attempting to minimize total risk through complete

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and has a three- to five-year establishment period, so trials are very costly and have a very long time-lag.

[224] Bogetoft & Olesen, *supra* note 88, at 198.

[225] *Id.*

[226] *See supra* notes 80–88 and accompanying text.

contract design is difficult to achieve and incurs its own set of costs. Accordingly, assigning price risk between the parties is one of the most important provisions in biomass production contracts. Several common pricing provisions have been considered in the literature,[227] the simplest of which offers a set price per unit of biomass throughout the duration of the contract. While this assigning of price risk eliminates the producer's exposure to all down-side price risk, it also eliminates the potential for higher gains, should the value of biomass or crop substitutes increase. An acreage contract that compensates the producer only by acres of production has similar price risk consequences, while also introducing yield risk. Cost-plus pricing eliminates all producer down-side price risk by setting a fixed profit margin, and also addresses input price risk. Similarly, escalators based on input costs (e.g., fertilizer) is another technique to minimize producer price risk and may be especially important in perennial cropping systems in which producers are locked into a crop choice for extended periods.[228] On the other hand, indexed pricing provisions may grow in popularity, where the price of the biomass is tied to commodity prices or other benchmarks that fluctuate over time.

Different producers, however, may prefer different pricing provisions, based on their individual risk tolerances and marketing skills. Producers with low risk tolerance will likely prefer fixed pricing schemes, or guaranteed minimum revenue provisions. Producers with high risk tolerances and marketing ability may prefer indexed pricing arrangements[229] to allow opportunities for windfall profits. Opportunity cost pricing, in which the contract ties the price of biomass to the substitute

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[227] *See, e.g.*, Larson et al., *supra* note 82, at 3–4.

[228] Beyond the moral hazard issues, producers face considerable price risk with the variability of the cost of inputs, including fertilizer and chemicals. Several potential solutions exist to transfer this risk to the end-users. Some contracts may provide for "cost-plus pricing" compensation provisions, where the producer is compensated for all "eligible costs of production" plus a margin for profit. *See* Allen, *supra* note 200, at Exhibit B, Schedule 1 (providing an example of "Cost-Plus Bases for Biomass").

[229] For a description of index pricing, see *supra* note 206 and accompanying text.

ventures of the producer (e.g., grain production cash rent, CRP rental payments, etc.) provides yet another option. Information asymmetry in the producer's favor regarding pricing, however, allows an extraction of information rents from the end-user in the form of higher compensation levels. It is in this context that all the adverse selection tools become relevant: rationing, signaling, screening, signaling, and auctions.

A rationing strategy of a fixed price per ton excludes producers that cannot turn a profit at the pre-determined level, and allows more efficient producers to gain information rents. This strategy, however, limits supply by excluding potential higher cost producers—a potentially costly strategy when a stable, low-cost supply is the most important end-user objective.[230] Screening strategies to decrease information rents may increase supplies slightly, but developing optimal contracts to satisfy the incentive compatibility and participation constraints of all producer types is difficult and requires extensive information. What seems more feasible is for end-users to offer multiple compensation provisions (e.g., index pricing and acreage-based pricing) to enable choice based on their risk tolerances. While this method does not address producers' opportunity cost information, it is a simple way to address risk tolerance information, and avoids premiums for risk-averse producer acceptance of high-risk compensation provisions. A more complete analysis and discussion of screening to determine appropriate pricing provisions and contracts is beyond the scope of this paper, but merits further research.

Signaling strategies may benefit both end-users and producers. End-users can establish eligibility requirements and collect observable information on local producers, thereby facilitating discriminatory pricing based on producer characteristics. For example, producers who (1) are closer to the end-user; (2) have a large amount of marginal land; or (3) already possess biomass compatible equipment, are presumed to have lower opportunity costs, and may accept lower prices. Producers without these characteristics are presumed to have

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[230] *See supra* note 105 and accompanying text.

higher opportunity costs, and thus warrant higher compensation. In negotiating for compensation, these high-opportunity cost producers can signal characteristics that are difficult to fake (e.g., proximity to biomass conversion facility or transportation networks) to gain higher compensation relative to others.

Finally, creative end-users may choose to set prices by reverse auctioning.[231] This method may only be feasible after end-users have secured sufficient interest from producers to ensure competitive pricing, which may only be possible once the industry is more developed. In this method, the end-user would auction off standard allotments of "biomass production rights." To illustrate: the end-user would determine the amount of biomass needed to keep the plant at full capacity for a year, say 1 million tons. The end-user would then break this total capacity into standard contracts—perhaps 5,000 contracts of 200 tons. The end-user would then begin reverse auctioning the production rights, starting with a high bid and quoting lower prices until a single producer is left willing to produce at that price. That producer can then state how many set contracts of production he is willing to produce at that price. The auction continues until all 5,000 contracts are purchased by producers. Within the contracts, producers would prefer the ability to transfer or assign production rights. This allows for producers to transfer the production rights to subsequent lower-cost producers over time, thus making the production rights a fungible asset, similar in form to a commodity.[232]

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[231] *See* Bogetoft & Olesen, *supra* note 88, at 194 (describing a similar structure in the potato industry). Of course, developing the auction model would present significant challenges. Administering and designing the auction and enforcing production contracts would be difficult and costly. And, last but not least, a critical mass of biomass producers is necessary to ensure competitive bidding on production rights, and prevent opportunistic behavior—an unlikely scenario in this nascent industry.

[232] To illustrate, consider a producer who has contracted for five 200-ton contracts at $50/ton. In a poor crop year, he may not be able to satisfy his contract obligations. He may then transfer his production rights to a producer that may have a surplus. If the other producer can produce the biomass for less than $50/ton, gains will result from the trade that can be allocated to either or both parties, and prevent penalties from production shortfalls. In this way, end-

b. *Yield Risk*

Generally, producers might prefer to transfer all yield risk to the end-user through provisions, such as the acreage contract. This is consistent with the Risk-Minimizing perspective implication to loosen incentives to decrease producer risk.[233] The moral hazard that this creates can be addressed through management strategies, such as monitoring. When end-users are unwilling to accept all yield risk,[234] or are unable to adequately deal with moral hazard through monitoring and increased control, yield incentive contracts may be necessary. In fact, where the specific risks that affect yield are adequately addressed, incentive (tournament) contracts may be equally acceptable to producers. In these contracts producer incentives are based on performance relative to other similar producers, rather than absolute measures of performance (e.g., yield) that are subject to common risks that affect all producers equally (e.g., weather).[235] By creating relative performance incentives, end-users can address moral hazard problems without shifting the incidence of common risk to producers.[236] Contracts can further reduce common risk by grouping producers according to characteristics, such as by geography for weather risk and

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users also obtain a more secure biomass supply.

[233] *See supra* notes 148–51 and accompanying text.

[234] Yield risk is the aggregate of many more specific production cycle risks that have been addressed in this paper (e.g., weather, pest, mismanagement, etc.).

[235] Bogetoft & Olesen, *supra* note 88, at 193. In tournament contracts, it is important to compare apples to apples (e.g., seed stock, location, crop type, planting dates) and account for the inability of farmers (especially initial adopters) to change varieties as perennial cropping systems cannot take advantage of newer, higher-yielding varieties. For example, *Miscanthus* and switchgrass both have life-cycles beyond ten years, and thus producers are locked into the same variety for an extended period of time. As newer, more profitable varieties are developed, producers are at a competitive disadvantage with later producers. In drafting yield incentive provisions, contracts should take this dynamic into account to avoid penalizing the early adopters. This practice should also address the yield variance for *Miscanthus* and switchgrass over the production cycle of the crops as early yield comparisons should account for the longer establishment time for perennials.

[236] *Id.*

planting dates for other production risk.[237] This reduction of common risk, however, may not eliminate idiosyncratic risks of producers, such as disease outbreaks, equipment failures, etc., and end-users retain some yield risk as they are not guaranteed a fixed amount of biomass for the conversion facility.[238]

Contracts should also address the consequences of a production surplus. Under an incentive contract, producers would prefer no maximum delivery amount. End-users, however, may desire a delivery ceiling to limit end-user waste when biomass production outstrips conversion facility capacity. Due to the extreme asset specificity of the surplus biomass in a nascent market, the end-user may retain all bargaining power for spot market purchases of surplus production.[239] Where other buyers exist, producers may try to increase property rights and bargaining power by retaining ownership of any surplus yield. For example, the contract could explicitly reserve any production surplus over the maximum to the producer or preserve the right of the end-user to request surplus biomass priced under the contract's default compensation provision.[240]

On the other hand, contracts also must consider allocation of catastrophic risk. Over time, it is likely that weather, pests, drought, flooding, wind, or hail will impact biomass production on a given farm. Producers traditionally deal with these catastrophic risks through the use of federal crop insurance.[241] No such product exists for biomass as of this writing.[242] End-

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[237] *Id.*

[238] *Id.*

[239] According to Williamson, industries with high levels of asset specificity tend (1) to utilize more vertical coordination and tend toward vertical integration; and (2) to further eliminate opportunistic behavior among parties. *See generally* Williamson, *supra* note 90, at 253–54. These tendencies imply the principle that producers should more carefully consider possible contingencies where specific assets are involved (as well as high levels of uncertainty and frequency), and increase vertical coordination by negotiating more complete contract provisions. Another principle is that imbalances in bargaining power can be minimized when both parties make specific investments. Bogetoft & Olesen, *supra* note 88, at 194. Therefore, balancing the parties' investments and creating dependencies can decrease the risk of opportunism.

[240] *See, e.g.*, Allen, *supra* note 200, at §3.

[241] *See generally* Joy Harwood et al., *supra* note 50, at 48–55.

[242] *See* RISK MGMT. AGENCY, USDA, *Information Browser: County Crop*

users require a consistent supply to accommodate conversion facilities, but a biomass farmer that fails to harvest a crop (or experiences difficulty with crop establishment)[243] has no revenue to perform the contract via spot market purchases—especially when there is no spot market for biomass. Accordingly, contracts should specify conditions for performance excuse and contingency provisions. Moreover, in the absence of a government safety net along the lines of crop insurance, biomass contracts should consider minimum revenue provisions to provide the farmer with some compensation. One way to soften this effect on the end-user is through the use of an amortized payment schedule. Producers would receive a guaranteed cash flow during all years of production to cover costs, but later payments could be diminished to allow the end-user to recover the costs throughout the life of the contract. Contracts could also require crop insurance, once available, and use insurance proceeds to offset initial contingency provisions.

c. *Incentives*

Once the crop is established, producers face a number of issues during the growing phase. Some production contracts may require very specific production practices in order to decrease end-user supply risk and require monitoring of crop quality. These requirements decrease producer autonomy, and diminish potential gains from producers' individual management skills and experience. Heavy requirements may also restrict the

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Programs, http://www.rma.usda.gov/data/cropprograms.html (last visited Apr. 10, 2013).

[243] There are significant risks in crop establishment for some perenials. Establishing switchgrass and *Miscanthus* can be difficult, and the risk of crop failure is high. Producers may be unable to bear this risk and prefer that the contract assigns this risk to the end-user. Where the end-user agrees to share or finance establishment costs, the contract should include language providing for the cost of re-establishment. Where the producer must obtain third-party financing, producers should discuss the availability of a credit extension in the event of crop failure. If the producer is not willing or not able to bear the risk and cost of re-establishment, the contract must provide for the end-user to assume the risk and pay for re-establishment. Again, in the commodity crop context, there are "replant" insurance products in the event of establishment failure.

producers' flexibility to adjust management practices to various production environment scenarios.[244]

On the other hand, considerable production risk arises from inexperience and lack of knowledge with producing energy crops. Inexperience or ignorance may cause a producer to adopt a production practice harmful to the crop or environment.[245] In addition, the producer may be unsure how to address new production hazards, such as a new pest, drought conditions, or invasiveness. Thus, inexperience and lack of knowledge creates risks and costs for producers.

End-users may desire to increase producer control through the biomass production agreements. As a general rule, however, contracts should allow producers as much freedom as possible to choose production practices. A principle of the Sociological-Compatibility perspective is that producers value autonomy and demand compensation in some form for the loss of autonomy to satisfy participation constraints. Moreover, adjusting cultural practices is a traditional risk management tool for producers. For example, producers may choose to apply fertilizer in the fall to avoid higher prices in the spring, decide to plant later to avoid risk of a late frost and insect pests, and producers may choose to plant herbicide resistant crops and apply herbicides rather than mechanically cultivate crops to reduce weed competition. Because incentive contracts enhance producer risk, and rigid production practices foreclose other risk management strategies, other methods of dealing with end-user production risk are preferable. In other words, production practices have very poor separability, and thus respond poorly to incentives.[246] A better strategy may be for biomass production agreements to employ the use of generalized legal standards rather than specific practices to control production, which would shift contracting costs from the front to back end, while providing greater

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[244] *See supra* notes 72-76 and accompanying text (discussing cultural practices as a traditional agricultural risk management tool).

[245] For example, a producer might be unable to recognize a nutrient deficiency because of his inexperience with the crop, and thus fail to apply fertilizer that would greatly improve yield.

[246] *See supra* notes 149–55 and accompanying text.

producer autonomy.[247]

A singular focus on incentives to maximize yield, however, is fraught with potential downside risks to long-term sustainability and suitability with end-user needs. For example, there is a tradeoff between corn stover removal, soil erosion, and fertilizer inputs. Removing high percentages of crop residues increases the risk of soil erosion from water and wind.[248] Excess stover removal to increase per acre yield in one year will require additional fertilizer for the following crop year.[249] Excess fertilizer can then impact the composition of the resulting biomass, especially its mineral content, which can then impact the ethanol conversion process. Additional fertilizer application also shifts the carbon footprint of the biomass feedstock or precipitates other environmental externalizes (e.g., nitrate pollution in water). Research also has suggested that the loss of soil organic carbon serves as an additional constraint for corn stover harvest.[250] Similarly, harvest timing and cutting depth of both corn stover and perennial biomass crops must balance yield,[251] moisture content,[252] nutrient storage in the rootstock,[253]

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[247] *See* Scott & Triantis, *Incomplete Contracts*, *supra* note 140, at 197. In addition to the common legal standards, such as good faith, substantial performance, and reasonable care, *see id.* at 187, many agricultural contracts include best farming practices and good husbandry provisions. Neil D. Hamilton, *Legal Aspects of Farm Tenancy in Iowa*, 34 DRAKE L. REV. 267, 306–08 (1984). While these terms do not specifically state the obligations of the parties, they increase freedom to operate, *see* Scott & Triantis, *Anticipating Litigation*, *supra* note 173, at 835–39, and can draw on the long background of contract law in the specialized context of agriculture.

[248] Graham et al., *supra* note 12, at 3; David A. Glassner et al., *Corn Stover Collection Project*, published for presentation at BioEnergy '98: Expanding BioEnergy Partnerships at Madison, Wis., Oct. 4-8, 1998, 1100, 1101 (1998), *available at* http://www.agmrc.org/media/cms/bio98paper_CA9EFF13F9159.pdf.

[249] Hoskinson et al., *supra* note 209, at 130.

[250] W.W. Wilhelm et al., *Corn Stover to Sustain Soil Organic Carbon Further Constrains Biomass Supply*, 99 AGRONOMY J. 1665, 1666 (2007).

[251] I. Lewandowski et al., *Miscanthus Experience with a Novel Energy Crop*, 19 BIOMASS & BIOENERGY 209, 220 (2000) (noting that lodging and leaf loss from winter conditions can reduce yield by 3% to 25%).

[252] Hoskinson et al., *supra* note 209, at 130; Shahab Sokhansanj et al., *Engineering Aspects of Collecting Corn Stover for Bioenergy,* 23 BIOMASS & BIOENERGY 347, 348, 350 (2002); Ercoli et al., *supra* note 12, at 4, 10.

[253] Heaton et al., *supra* note 12, at 442.

soil compaction,[254] and wildlife habitat over the winter. At the establishment stage, producer discretion in initial crop variety selection could impact potential invasiveness or migration of genetically engineered plants.[255] Accordingly, incentives in biomass supply contracts should provide producers sufficient flexibility to manage production and harvest decisions within the context of their other farming operations (e.g., windows for grain harvest for mixed-production farms) and long-term environmental values.

As discussed in more detail in Section IV, *infra*, sustainability standards address many of the environmental tradeoffs identified above and embed balancing criteria to allow for producer autonomy within the context of environmental, social, and economic sustainability.[256] Incentive contracts could look to or even incorporate third-party sustainability certification programs for guidance in allocating risks and responsibilities among producer and end-users with respect to balancing yield with environmental impacts.

In addition to, or complementary with, third-party sustainability certification, monitoring through the use of fieldmen may provide the most favorable strategy to address moral hazard during establishment and maintenance. Although developing the fieldmen model may take time, the benefits discussed in the framework likely outweigh the costs. Contracts can incorporate this model by elaborating on the "cooperation

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[254] Ercoli et al., *supra* note 12, at 10.

[255] Because large-scale production of switchgrass and *Miscanthus* has not been present in the United States and long-term performance is unknown, researchers are concerned that the rigorous nature of these biomass crops will create invasiveness problems. For example, although *Miscanthus x giganteus* does not produce viable seed, crosses between M x G and seeded ornamental varieties could produce viable seeds and pose a greater risk of invasiveness. Heaton et al., *supra* note 12, at 441. Moreover, as biomass production gains traction, genetically modified (GM) seedstocks are likely to be developed. These GM varieties may create unique environmental hazards, including an increased likelihood of invasiveness or contamination of neighboring crop varieties. Given the many unknowns of large-scale biomass production at this time, other environmental hazards may arise. While the assignment of liability for these hazards is uncertain, it is nonetheless advisable that the producer and end-user discuss allocation of potential environmental liability.

[256] *See infra* notes 279-82 and accompanying text.

provision" outlined in the information sharing section. In addition to requiring notification of any material change in circumstances that may affect performance of either party's obligations, the contract could create a right of the end-user to inspect the producer's premises.[257] In order to be of value to producers, end-users should employ the services of agronomists or individuals with knowledge and experience in biomass crop production, a requirement likely worth adding into the contract. Qualified fieldmen also can provide an excellent avenue for information sharing and education—an important risk management tool. In addition to inspections, the contract should authorize producers to request fieldmen services. Moreover, fieldmen could be enabled to authorize contract modifications or excuse performance. This strategy enhances producers' social interaction factors,[258] and could be coupled with assistance for sustainability standard certification.

d. *End-Product Specifications, Storage, and Delivery*

i. *Product Specification*

End-users deploy biomass production agreements to secure a stable supply of biomass, as well as other important characteristics, such as moisture level, foreign matter, mineral profile, BTU content, size and shape, and its environmental footprint.[259] Risk arises when the producer is required or

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[257] *See* Michael Allen, *Biomass Production Agreement,* Exhibit D, General Conditions (Nov. 4, 2010), *available at* http://energyindependence.wi.gov/docview.asp?docid=20757&locid=160.

[258] *See supra* notes 33-44 and accompanying text.

[259] Different harvest methods have consequences for yield, moisture, and quality of the biomass. For example, cutting and shredding allows for higher yield and easier collection by separating the stalks from the ground, but this adds an additional costly step in harvest. S. Sokhansanj & A.F. Turhollow, *Baseline Cost for Corn Stover Collection*, 18 APPLIED ENGINEERING AGRIC. 525, 526 (2002). Also, larger pieces make better bales, but smaller pieces of residue will dry quicker, creating another tradeoff. *Id.*; Sokhansanj et al., *supra* note 252, at 349. All these issues become more complicated when producers contract with third parties to harvest, a practice that is likely to become common due to specialized equipment needs. *See, e.g.*, Glassner et al., *supra* note 248, at 1100. Relinquishing control over some parts of the harvest process by contracting with third parties creates counterparty risk for producers and requires additional

incentivized through penalties or bonuses for these crop attributes. While the producer may have control over some attributes, others (e.g., mineral content) evade manipulation. Strict consequences, such as rejection or price docking, create large risks for producers. Moreover, when minimum requirements are defined loosely, end-users may be able to engage in opportunistic behavior. To minimize holdup, biomass contracts should incorporate reasonable margins of error to account for normal environmental characteristics, as well as procedures for third-party verification and re-measurement.

ii. *Storage and Transportation*

Storage and transportation of the low-density, high-volume biomass from the producer to the end-user presents unique challenges[260] and should be considered carefully in the biomass supply contract.[261] Assigning responsibility for storing and transporting implicates both risk- and cost-minimization strategies of contract design. For example, a set delivery date in the contract provides certainty, but indirectly assigns the storage burden—perhaps to both parties—and requires careful planning. On the other hand, an "on end-user demand" clearly shifts responsibility for storage to the producer and may dictate harvest timing despite other agronomic or environmental considerations. In contrast, an on-harvest delivery term places

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coordination. Finally, transportation of the biomass from the producer to the end-user creates numerous issues to be resolved between the two parties. Transporting and storing biomass presents unique challenges because of the low density and high volume of the product, *see* Taylor & Youngs, *supra* note 13, at 12, and is beyond the scope of this paper. *See* Heaton et al., *supra* note 12, at 447. ("the crop must then be parceled in a form suitable for transportation and then processed to be useable by the power station."). For example, the contract may require round bales to be wrapped in plastic mesh to shed water and decrease spoilage, and to prevent bursting. *See* Glassner et al., *supra* note 248, at 1102. Square bales can be more dense and larger, but require indoor storage. Bale density and size may be regulated to ensure uniformity and decrease transportation and space costs. *See id.* at 1103.

[260] To illustrate, it is estimated that in order to supply a 50-million-gal/year biofuel refinery for a year, one hundred acres of storage are required. Larson, *supra* note 49, at 44.

[261] *See* Taylor & Youngs, *supra* note 13, at 12.

storage responsibility—and attendant risk of loss[262]—on the end-user. Transportation responsibilities tie directly into product specifications and storage. If the contract requires certain harvesting methods or preprocessing requirements, such as pelletizing or densification, the farmer may incur significant up-front equipment costs to produce the required result.[263] However, some producers seek flexibility to minimize processing and transportation costs, such as forage chopping, directly into road transportable wagons, or pelletizing biomass in the field to decrease volume.[264] In sum, up-front consideration should be given in the contract to linking product specifications with optimal storage methods to minimize post-harvest loss and maximize transportation efficiencies. The very high level of asset specificity, along with specialized equipment, places significant post-harvest risk in the farmer who has little bargaining power in a single-buyer market. Accordingly, a more complete contract to minimize hold-up risk may be necessary to induce contract acceptance by the farming community.

4. Property and Production Issues: Land Acquisition and Ancillary Property Rights

a. *Acquiring Farmland*

From a producer perspective, several factors influence the choice of land for biomass production. Perhaps most important is opportunity cost. In the Midwest, where much of the land is highly productive and can support currently higher value crops (e.g., corn or soybeans), energy crops, such as *Miscanthus* and switchgrass, are unlikely to compete for scarce land resources.[265]

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[262] Different storage methods result in tremendous differences in spoilage and quality loss; for example, storing bales with direct contact with the ground can create losses of 40-60%, and losses of uncovered bales can be up to 45%. *Id.* at 13. Storage methods that decrease spoilage are costly; such practices include: pouring concrete or gravel pads, stacking bales, wrapping bales with cloth or plastic, building structures to store bales under roof, or even constructing anaerobic storage. *Id.* Perhaps the largest concern with storage is the risk of catastrophic loss due to fire, wind, or other catastrophe.

[263] *See id.* (briefly discussing pelletizing).

[264] *See, e.g.*, Heaton et al., *supra* note 12, at 447–48.

[265] Corn stover can, of course, be harvested from any land on which corn is

Biomass may be relegated to more marginal lands with lower opportunity cost, such as pasture or hay ground. Perennial biomass crops do provide, however, a number of environmental benefits, such as erosion control, improved soil and water quality, increased wildlife habitat, and increased soil organic carbon.[266] Producers, therefore, may want to take advantage of these benefits and grow energy crops on at least marginal land to provide these long-term and environmental benefits. In addition, studies have shown that soil types can affect the composition of biomass plants, such as the percentage of lignin, cellulose, ash, and mineral content.[267] In this way, land choice can significantly influence the quality and value of the resulting biomass crops.

End-users have two strong preferences concerning the choice of land. First, in order to secure a stable biomass supply, end-users would prefer to tie biomass production to land title, rather than tying production requirements to individual producers. This strategy permits end-users to be less concerned with producer default, as land resources remain dedicated for biomass production. Other than outright purchase of land by the end-user, more creative avenues exist, such as equitable servitudes, covenants, or easements, to produce biomass that would attach to land title and provide more supply security than long-term lease agreements.

Second, end-users prefer that biomass production be located near the end-user's facility to decrease transportation costs. Where the end-user assumes the responsibility of transporting the biomass, local production is especially important. Longer transportation routes also increase greenhouse gas emissions, thereby decreasing the energy balance of the crop. Local

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produced, but highly erodible land creates erosion constraints that greatly limit the amount of corn stover that can be removed. *See* Scott Malcolm & Marcel Aillery, *Growing Crops for Biofuels Has Spillover Effect*, 7 AMBER WAVES 10, 15 (2009), *available at* http://www.ers.usda.gov/AmberWaves/March09/PDF/Biofuels.pdf. As a result, the land that will be used for corn stover production will likely be different from the land used to produce switchgrass and *Miscanthus*.

[266] Jensen et al., *supra* note 6, at 773–74.

[267] Lewandowski et al., *supra* note 251, at 220.

production creates cost and risk for producers in two main ways, however. First, producers lose the traditional agriculture risk management strategy of geographical diversification; they cannot spread out production over larger areas to decrease weather and pest risk. Second, requiring local production limits the producer's ability to produce energy crops on marginal ground[268] or land exiting the Conservation Reserve Program.[269]

These production dynamics create a number of concerns for producers. First, as discussed in the Sociological-Compatibility Perspective, a producer may be unwilling to relinquish that level of control over his land; producers' land is usually their most critical asset. Second, the greater the degree the land title is locked into biomass production, the greater the level of asset specificity, increasing the risk of holdup or renegotiation. Moreover, most producers grow crops on a combination of owned and leased land, with farmers depending on rental land resources to achieve economies of scale. Tying biomass production to land title, therefore, tightens the producers' participation and incentive compatibility constraints and necessitates higher compensation.

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[268] *Cf.* Bogetoft & Olesen, *supra* note 88, at 190 (providing an analogy).

[269] Although not available at this time, agricultural policy makers and producers have suggested another strategy to address the lack of cash flow as well as to promote environmental policy. *See, e.g.*, *Biomass from Former CRP Land Could Fuel Cars or Heat Homes*, W. LIVESTOCK J., Mar. 5, 2012, at 27. In order to utilize marginal land and capture the environmental benefits of energy crops, producers would prefer to roll expiring Conservation Reserve Program (CRP) acreage into energy crop production. Energy crop production does not comply with current CRP guidelines, as crops cannot be continuously harvested from dedicated CRP acreage, except under managed harvesting plans approved by the Commodity Credit Corporation of the Department of Agriculture. *See* 7 C.F.R. § 1410.63(c)(1) (2010) (limiting biomass harvest periods to those times outside of nesting and broodrearing season, and requiring a payment deduction on the part of farmers under contract of the CRP). However, producers would like to use the final three to five years of expiring CRP contracts to establish long-term perennial energy crops. Although it would require a change in policy, producers can then collect the last of the CRP payments during the establishment of the energy crop. This "subsidy" creates a strong incentive for producers to produce energy crops on the nation's marginal land, utilizing the environmental benefits of *Miscanthus* and switchgrass. These two crops, among other perennials, have been shown to provide excellent erosion control, wildlife habitat, and increased water quality.

On the other hand, the multi-year production cycle for perennial biomass crops injects unique risk concerns into the farmland rental market. Producers may have difficulty securing leases for the duration of the production contract or even the life-cycle of crops, such as switchgrass and *Miscanthus*.[270] Moreover, landowners may be concerned with the short- and long-term effects of biomass production on the land itself, or how to remediate the land back to its prior use if the end-user defaults on the biomass supply contract—a particular concern due to asset specificity. To provide safeguards and regulate producer practices, traditional leases have often relied on legal standards (e.g., "best farming practices") and duties (e.g., "farm faithfully and in a timely, thorough, and businesslike manner").[271] These standards have less meaning with the production of a new crop type, and thus create uncertainty and potential for conflict between tenants, landlords, and end-users seeking control over the production process. Landowners may want to ensure the crops or the producers' cultural practices will not cause long-term harm to the land, creating another moral hazard problem and requiring landowners to increase control or monitor producer behavior.[272] One possible solution could be the establishment of bonding requirements for remediation, similar to those imposed on biomass plantings in Florida larger than two acres.[273] Bonding provisions could be incorporated into both the rental lease and the biomass production contract.

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[270] The long-term nature creates higher levels of price and asset risk as changes occur in the value of land and profitability of traditional crops. Landowners may then prefer indexed rent payments tied to outside markets to account for long-term price changes. These payments transfer price-risk to the producers. For crop-share leases, the unfamiliarity of landowners with energy crop inputs and marketing creates moral hazard problems, as the information asymmetry in the producer's favor allows for more opportunistic behavior. Thus landowners may demand cash-rent leases with substantial premiums.

[271] *See, e.g.*, Donald L. Uchtmann & Dennye Ehrnwald, FARMDOC, University of Illinois at Urbana-Champaign, *Illinois Cash Farm Lease*, 3, http://www.farmdoc.illinois.edu/legal/Farmdoc_Form_CL01_0912.pdf.

[272] Examples include soil samples and monitoring for the spread of potentially invasive biomass crops.

[273] FLA. STAT. § 581.083(4) (2011); FLA. ADMIN. CODE ANN. r. 5B-57.011 (2011).

If producers, in spite of these concerns, are able to secure leases for an extended length of time, they remain highly exposed to termination or default by the landlord; if the landlord defaults, the producer remains bound to a biomass production contract without sufficient land upon which to grow the crops. On the other hand, if a producer desires to exit the biomass industry, or becomes unable to continue production for any reason, he faces the risk of being locked into an undesirable long-term lease. Likewise, landowners, due to high asset specificity and the nascent character of the bioenergy industry, face a relatively higher risk of default by both tenants and end-users.

The issues discussed above illustrate the importance of specifically considering land tenure within the biomass supply contract and linking the provisions to specially tailored farmland leases for biomass production. Moreover, biomass supply contract duration should align with crop life cycles, which should align with land lease terms.

b. *Ancillary Property Rights: Germplasm and Ecosystem Service Payments*

Access to land, while the most important consideration in negotiating biomass supply contracts, is not the only issue warranting attention. Control of germplasm, whether conventionally bred or through advanced genetic engineering technologies, is an essential element of intellectual property rights protection.[274] Contractual agreements embedded within intellectual property licenses can impose restrictions on the grower.[275] Many of these restrictions currently used in the agro-biotech industry go far beyond mere protection of intellectual property rights (e.g., seed saving prohibitions) and dictate specific agronomic practices of the farmer. The use of germplasm contracts (either independently or within the general biomass

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[274] *See generally* A. Bryan Endres & Peter D. Goldsmith, *Alternative Business Strategies in Weak Intellectual Property Environments: A Law & Economics Analysis of the Agro-Biotechnology Firm's Strategic Dilemma*, 14 U. ILL. J.L. TECH. & POL'Y 237 (2007).

[275] A. Bryan Endres, *State Authorized Seed Saving: Political Pressures and Constitutional Constraints*, 9 DRAKE J. AGRIC. L. 323, 325 (2004).

supply contract) could be structured to specify inputs (plant variety, chemicals), farming and harvesting practices (segregations or isolation measures, equipment cleaning, monitoring for invasive tendencies), post-harvest disposition (biofuel conversion), and post-contract actions (control of remaining rootstock, volunteer plants). From the producer's perspective, growers may wish to expand their own production by harvesting rhizomes from their fields. This practice especially is likely in the early stages of industry maturity when rhizomes or specialized seeds may be hard to procure. Biomass supply contracts, therefore, should specifically address intellectual property rights in germplasm and ensure compatibility with germplasm agreements.

A second ancillary issue relates to the positive externalities derived from certain agronomic practices associated with perennial biomass cultivation. Planting *Miscanthus* or other bioenergy crops may control erosion, improve water quality, sequester carbon, and increase wildlife habitat. In the future, ecosystem service markets may reward these practices. Accordingly, the biomass supply contract and, if applicable, the farmland lease should specify which party may participate, and thus receive the benefits, in ecosystem service markets.

5. Duration/Assignment/Renewability

The duration of the biomass production contract has serious consequences for producers, but will likely be driven from the end-user's perspective. This is because end-users must secure a stable biomass supply for the duration of the investment cycle of the conversion facility, likely at least 20 years.[276] Offering contracts for less than the optimal investment cycle creates supply risk for the end-user and potential holdup issues. Long-term contracts are somewhat less critical for producers, as dedicated energy crops can be destroyed and the land returned to traditional cropping methods with comparatively lower cost. Nonetheless, in electing to produce perennial crops, producers

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[276] *See* G. Jungmeier et al., *Environmental Burdens over the Entire Life Cycle of a Biomass CHP Plant*, 15 BIOMASS & BIOENERGY 311, 316 (1998) (assuming that a biomass conversion plant would last twenty years).

also make long-term commitments by establishing a crop with a production cycle that could reach 15 years. Moreover, producers may wish to renew contracts, particularly if the life cycle of the established crop outlasts the initial contract term.

To address these concerns, contract length should correspond with crop life-cycle to ensure producers can recover establishment costs and obtain adequate return on investment. Shorter durations, due to asset specificity, give rise to holdup risks. In situations in which the life-cycle of the crop outlasts the duration of the contract, the producer can reduce the risk of holdup by negotiating renewal options.

A corollary to the renewal provision is the ability to assign biomass production to another farmer. As the end-user's primary concern is securing a stable supply of biomass, incorporating assignment clauses in the initial agreement can provide a seamless escape hatch for farmers no longer interested in producing biomass as part of a long-term contract. Assignment clauses may minimize potential supply disruptions and serve as a "next best" strategy compared to attaching production contracts to land title.

However, due to the vertically coordinated nature of the bioenergy industry, the extent to which individual producers may negotiate the contract provisions discussed in this section remains to be seen. Nonetheless, the authors recommend that end-users seeking a stable, long-term biomass supply chain at a low overall cost should consider the issues identified above, as biomass production agreements that incorporate the socio-compatibility perspective, along with risk- and cost-minimization, are more likely to result in more secure supply chain relationships.

IV.

CONCLUDING THOUGHTS: "SUSTAINABLE" BIOMASS CONTRACTING

Incorporating a combination of the solutions detailed above into biomass production contracts will substantially address the costs, risks, and sociological concerns of producers and end-users. This should improve contract negotiation processes and improve supply chain stability. Moreover, as the biomass industry matures and follow-on issues arise, the proposed Biomass Contracting Framework can serve as an important point of departure in obtaining negotiated solutions. In addition to the framework described above, the development of sustainability standards tailored to the biomass industry, such as the Council on Sustainable Biomass Production (CSBP)[277] or Roundtable on Sustainable Biofuels (RSB),[278] can provide further support to improved biomass contract design. By focusing on long-term sustainability, these standards can use market forces (i.e., certification-driven marketing claims) to provide additional incentives for end-users to approach contractual relationships beyond the archetypal cost- and risk-minimization perspectives.

For example, the RSB's socioeconomic principle requires skill training that is culturally sensitive and respective of existing social structures.[279] Although the intent of this provision is to apply within the context of impoverished regions, most likely in the developing world, the underlying sustainability benefits of cultural sensitivity in skills training certainly would hold true in domestic biomass contracts between end-users and producers. In the current climate of adhesion-type contracts presented by biomass end-users, producers could reference the internationally accepted RSB standards within their limited contract negotiations as support for professional development, formation of peer groups, and even feedback mechanisms, such as fieldmen services.

Sustainability standards for environmental criteria, such as biomass residue removal, compaction, erosion, soil carbon

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[277] *See* Council on Sustainable Biomass Production, *Standard for Sustainable Production of Agricultural Biomass* (June 6, 2012) [hereinafter CSBP Standard], *available at* http://www.csbp.org/Portals/0/Documents/CSBP%20Standard%20For%20Sustainable%20Production%20of%20Agricultural%20Biomass%2006122012_1.pdf.

[278] *See* Roundtable on Sustainable Biofuels, *RSB Principles & Criteria for Sustainable Biofuel Production* (Mar.1, 2011) [hereinafter RSB Standard], *available at* http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Version%202/PCs%20V2/11-03-08%20RSB%20PCs%20Version%202.pdf.

[279] *Id.* at Criterion 5.a. The CSBP provides a similar reference to worker training and to distribution of socioeconomic opportunity among stakeholders. *See* CSBP Standard, *supra* note 277, at Principle 6.

maintenance, and restrictions on introduction of potentially invasive energy crops,[280] also may have positive cross-over effects on biomass contract design. Incorporating environmentally-based sustainability standards into biomass contracts sends a signal to the producer of the perceived environmental credibility of the practice,[281] and lessens producer concerns regarding land stewardship and conversion from familiar cropping systems. Moreover, many of the producer autonomy concerns and cultural risk management practices identified in the social compatibility discussion in Part I.A, find resonance within these environmental standards. On the other hand, unduly restrictive practices embedded in a sustainability standard could discourage producer acceptance, if these criteria sacrifice traditional agricultural risk management practices, such as pesticide application. Nonetheless, the incorporation of sustainability standards within the biomass contract may provide a novel means to bring together divergent views of risk management, cost-minimization, and social compatibility to create a more stable, and ultimately profitable, biomass supply chain. In the future, end-users may be able to use contractual mechanisms to coordinate efforts within its "fuel shed" to achieve greater economic and environmental sustainability.

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[280] *See* CSBP Standard, *supra* note 277, at §2 (soil), §3 (Biological Diversity) and §4 (water).

[281] *See* Pannell, *supra* note 25, at 1415.