U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BIOENERGY TECHNOLOGIES OFFICE

Idaho National Laboratory

ECOSTRAT

FRAMEWORK FOR BIOMASS SUPPLY CHAIN RISK STANDARDS

AGRICULTURAL RESIDUE

Introduction

04/12/2019

The United States Department of Energy's (USDOE) Bioenergy Technologies Office (BETO) has tasked Ecostrat Inc. and Idaho National Labs (INL) with development of a systematic, standardized framework for assessing biomass supply chains. The goals are to clarify biomass feedstock risk for the capital markets, eliminate the needless economic "drag" of inflated capital and debt costs, and thereby unlock significant development potential in the bio-economy.

Inflated capital costs are linked to a lack of clarity on the part of capital markets around biomass feedstock risk—and this lack of clarity, in turn, is the result of the multiple, non-standardized approaches to quantifying that risk that exist today.

These new *National Standards for Biomass Supply Chain Risk* (*BSCR Standards*) are a standardized biomass feedstock risk assessment protocol designed to enable the capital markets to more accurately quantify bio-feedstock risk, and reduce the level of uncertainty that is currently a significant driver of low bio-project credit ratings and high capital costs.

Development of *BSCR Standards* supports the goal of a viable, sustainable domestic biomass industry that produces renewable biofuels, biochemicals, bioproducts and biopower by decreasing capital market risks to investment in bio-economy projects, and by increasing the number of projects that pass the crucial financing stage. The *BSCR Standards* also align with the goals and recommendations of the *Bioeconomy Initiative: Implementation Framework* issued Biomass Research and Development Board (co-chaired by U.S. Department of Energy (DOE), U.S. Department of Agriculture (USDA), U.S. Department of Transportation (DOT), U.S. Department of the Interior (DOI), U.S. Department of Defense (DoD), U.S. Environmental Protection Agency (EPA), National Science Foundation (NSF), and the Office of Science and Technology Policy (OSTP) within the Executive Office of the President.

These new *Standards* represent the current state-of-the-science in terms of quantification of biomass supply chain risk. It is our intention and goal that the *BSCR Standards* be integrated into the range of risk assessment tools used by the financial markets when evaluating biomass-based investments in order to accelerate the flow of needed capital into the biofuel, biochemical, bio-energy and bioproduct sectors.

Sincerely,

Jordan R. Solomon
President
ECOSTRAT INC.

Acknowledgements

Key Authors and Project Management

Jordan Solomon
President & CEO
Ecostrat Inc.
Jordan.Solomon@ecostrat.com

Marcin Lewandowski
Director of Risk & Analytics
Ecostrat Inc.
Marcin@ecostrat.com

Kevin Kenney
Director, Biomass Feedstock National User Facility
Idaho National Labs
kevin.kenney@inl.gov

Rachel Emerson
Research Scientist
Idaho National Labs
rachel.emerson@inl.gov

Shyam K. Nair
Group Lead, Process & Data Sciences
Idaho National Labs
snair@lanl.gov

Mark Elless
Technology Manager – Feedstock Supply & Logistics
Department of Energy BETO
mark.elless@ee.doe.gov

The authors would like to express gratitude to the following organizations and individuals for their contribution, guidance and support in the formulation of these BSCR Standards.

Financial Support

Advisory Committee

Richard Hess
Government Relations Director
Idaho National Laboratory
jrichard.hess@inl.gov

Kevin Kenney
Director, Bioenergy Program
Idaho National Laboratory
kevin.kenney@inl.gov

John Kirkwood
Partner
Krieg DeVault LLP, Faegre Baker Daniels LLP
john.kirkwood@faegrebd.com

Les Krone
Managing Director
Stern Brothers & Co.
lkrone@sternbrothers.com

Ryan Larsen
Professor - Applied Economics
Utah State University
ryan.larsen@usu.edu

John May
Managing Director
Hamilton Clark, Stern Brothers & Co.
john.may@hamiltonclark.com

Shyam K. Nair
Acting Manager, Data and Software Sciences Department
Idaho National Laboratory
snair@lanl.gov

Quang Nguyen
Process Demonstration Unit Lead
Idaho National Laboratory
quang.nguyen@inl.gov

Amy Schwab
Systems Integration Lead
Bio-Energy Technology Office, NREL
amy.schwab@nrel.gov

Sri Talluri
Professor
Michigan State University
talluri@broad.msu.edu

Ratings Review Committee

The authors are grateful to the members of the Ratings Review Committee for their ongoing support in developing risk rating protocols based on the BSCR Standards.

Michael Eckhart
Managing Director, Global Head of Environmental Finance
CitiGroup

Justin Goldstein
Vice President, Investment Banking Division
Goldman Sachs

Peter Johnson
Director, Environmental and Social Risk
Scotiabank

Greg Aguilar
Vice President, Clean Energy Finance & Leasing Manager Rabobank America

Dani Lipkin
Head, Business Development ETFs, CEFs, and Structured Notes
TMX Group, TSX Venture Exchange

Alvaro Andrada
Business Development Manager, Special Enterprise Risks Team Leader
Munich Reinsurance America, Inc.

Andrew Murfin
GM Advanced Biofuels
Shell International

Francois Ioos
Vice President, Biofuels Division
Total Raffinage Chimie SA

John May
Managing Director
Hamilton Clark

Pete Zaltz
Co-CIO & Head of Fixed Income
Gluskin Sheff

Emily Chew
Global Head of ESG
Manulife Asset Management

Larry Richardson
CEO
Re Energy Holdings LLC

Vivian Kan
Director, Cleantech Practice
Business Development Bank of Canada

Dr. Mark Summers
Executive Director, Technology and Innovation
Emissions Reduction Alberta

Ali Naqvi
Portfolio Manager, Real Assets Strategy
CPP Investment Board

Vanessa Chrifi Alaoui
Vice President, Structured and Trade Commodity Finance
BNP Paribas

Ryan Laverty
Manager, Power Marketing
TransCanada

Trystan Glynn-Morris
Project Finance Manager
Export Development Canada (EDC)

Anne-Catherine Mathiot
Managing Director, Head of Downstream & Marketing
BNP Paribas

Chris Tindal
Assistant Director and Business Team Lead
Commercial Aviation Alternative Fuels Initiative (CAAFI)

Gildas Poissonnier
Manager, Sustainability and Responsible Finance
Desjardins

Don Roberts
President and CEO
Nawitka Capital Advisors Ltd.

Mark Reidy
Partner
Kilpatrick Townsend

John Kirkwood
Partner
Faegre Baker Daniels LLP

Ted Todoschuk
Principal Researcher
ArcelorMittal Dofasco

Mittal Monani
Senior Trader Emissions
Direct Energy

Phil Cull
CEO, North America
Naturebank Asset Management Inc.

Chandra Ramadurai
CEO
Efficiency Capital

Cynthia Thyfault
Founder and CEO
Global Biofuture Solutions

Ian Thomson
President
Advanced Biofuels Canada (ABFC)

Bill Crump
Director
Leidos

Richard Nordin
Managing Director
Chatsworth Securities LLC

Scott Jacobs
CEO
Generate Capital Inc.

Rina Singh
Executive Vice-President
Alternative Fuels & Chemicals Coalition

Scott Gramm
Manager, Renewable Natural Gas
FortisBC

Mark Warner
Founder
Warner Advisors

Dr. Art Ragauskas
Professor/Governor's Chair in Biorefining
University of Tennessee – Knoxville

Sebnem Madrali
Research Engineer, Bioenergy Group
CanmetENERGY

Tim Marsters
Business Development, Energy Marketing and Trading
Centrica PLC

John Pierce
Partner
Perkins Coie

Jeff Manternach
CFO
Red Rock Biofuels

Jeanette Jackson
Managing Director
Foresight Cleantech Accelerator Centre

World Nieh
National Program Leader, Forest Products
United States Department of Agriculture (USDA)

Gene Lester
National Program Leader
USDA – Agricultural Research Service (ARS)

Peter Vadas
National Program Leader
USDA – Agricultural Research Service (ARS)

Industry Stakeholder Group

The Authors wish to thank the many individuals from over 150 US and Canadian Companies that make up the BSCR Standards Industry Stakeholder Group who have contributed their expertise, experience and time to the Standards.

Robert C. Abt NC State University	**Kyle Althoff** Equinox8	**Ira Altman** Southern Illinois University	**Dale Arnold** Ohio Farm Bureau Federation
Harold Arnold Hazlehurst Wood Pellets, Fram Renewable Fuels LLC	**Charlie Baylies** EWP Renewable Corporation, DG Whitefield LLC	**Peter Bloomfield** Concord Steam Corp., Phoenix Power Group	**Greg Branam** Florida Power Development
Jason Bergtold Kansas State University	**Bernard Brown** ARIES Clean Energy	**Jim Brown** Onalaska Bioenergy	**Krystel Castillo** University of Texas, San Antonio
Paolo Carollo Chemtex International Inc., Entsorga USA Inc.	**Kyla Cheynet** Drax Biomass Inc.	**Jacek Chmielewski** BioMass Solution LLC	**Rich Clasby** Detroit Stoker
Kevin Coleman Jefferies LLC	**Manish Consul** Kroll Bond Rating Agency	**Stacy Cook** Koda Energy LLC	**Jon Cozens** New Energy Risk
Alicia Cramer US Endowment for Forestry & Communities	**Bill Crump** Leidos (SAIC)	**Rob Crummett** Greenleaf Power Holdings	**Patrick Curran** Seaway Timber Harvesting Inc., Curran Renewable Energy
Chris Daly Oregon State University	**Matthew Darr** Iowa State University	**Mike Davis** NOVEC Energy Production	**Marin Dujmovic** Walker Industries
Laurence Eaton Oak Ridge National Laboratory	**Mahmood Ebadian** Biomass Supply Chain Consulting, University of British Columbia	**Jerry Ericsson** Diacarbon Energy, Merritt Wood Pellet and Torrefaction	**Glenn Farris** AGCO, Rentech
Sandy Ferguson Conifex	**Brandon Flake** Novo BioPower LLC	**Jason Gibson** Weyerhaeuser	**Andrew Giudici** Kroll Bond Rating Agency
Peter Glick Moody's Corp.	**Rajdeep Golecha** Zdaly	**Marinho Goncalves** Recast Energy	**Geoffrey Gunn** Prairie Climate Centre - IISD
Carlo Hamelinck Navigant Consulting, Inc.	**Jeongwoo Han** Argonne National Laboratory (ANL)	**Jason Hansen** Idaho National Laboratory	**Mike Halbleib** Oregon State University

Damon Hartley Idaho National Laboratory	**Dan Hayes** Celignis Analytical	**Maurice Hladik** Iogen Corporation	**Ted Howard** University of New Hampshire
Pat Howes Ricardo-AEA, Ricardo Building & Environment	**Ray Huhnke** Oklahoma State University	**James Hvisdas** Sweetwater Energy	**Joanne Ivancic** Advanced Biofuels USA
Sam Jackson Genera Energy	**Darrell Jenkins** Phoenix Power Group, Meadow Lake Bioenergy Center, Dixie Pellet	**Stephen Kaffka** University of California	**Sergios Karatzos** Steeper Energy
Doug Karlen USDA-ARS	**Alan Keller** POET	**Roger Kelly** Bliss Industries LLC	**John Kirkwood** Krieg DeVault LLP, Faegre Baker Daniels LLP
Jeff Kister Flag Leaf	**Sally Krigstin** Faculty of Forestry, University of Toronto	**Charles Lalonde** Ontario Federation of Agriculture	**Matthew Langholtz** Oak Ridge National Laboratory
Ben MacDonald Standard & Poor's Global	**Forcus Martinez** Prodesa North America	**Jessica (Brooks) Marcus** US Industrial Pellet Association (USIPA)	**Jonathan Martel** Compte Fournier
Anne-Catherine Mathiot BNP Paribas	**John May** Hamilton Clark, Stern Brothers & Co.	**Matt May** Weyerhaeuser	**Chris Mayo** Energy Vision LLC
Rob Mitchell USDA-ARS	**Lucy Mills** Enginuity Worldwide	**Pavel Molchanov** Raymond James	**Andrea Moran** Yield Power Group
Jeremy Mortl Messersmith Manufacturing	**Wendy Mussoline** Florida Energy Systems Consortium, University of Florida	**David Muth** EFC Systems	**Cristina Negri** Argonne National Laboratory (ANL)
Quang Nguyen Idaho National Laboratory	**Michael O'Leary** Bridgewater Power	**Vance Owens** South Dakota State University	**Barry Parrish** Georgia Biomass
Jeff Passmore Passmore Group Inc.	**Brad Perkins** Ohio Forestry Association	**John Pieper** Pioneer (Dupont)	**Gilles Plourde** Fike
John Rainey NOVEC Energy Production	**Brian Reed** Zilkha Biomass Energy, Highland Pellets	**Ben Reeves** Weyerhaeuser	**Gregory Remec** Fitch Ratings
Andrew Rodstrom GreenWood Resources	**Mark Riedy** Kilpatrick Townsend	**Robert Rummer** University of Kansas	**Angelo Sabatelle** Moody's Corp.
Corinne Scown Lawrence Berkeley National Laboratory	**Tom Schmid** Trans World Energy LLC	**Stephen Searcy** Texas A&M University	**Jaya Shankar Tumuluru** Idaho National Laboratory

Tat Smith Faculty of Forestry, University of Toronto	**Shahab Sokhansanj** University of British Columbia	**Colin South** LusBio	**Bill Smith** Idaho National Laboratory
Gregory Stangl Phoenix Energy Cabin Creek Biomass	**Inge Stupak** University of Copenhagen	**David Swan** eco-Options Energy Cooperative	**Sri Talluri** Michigan State University
Eric Tan National Renewable Energy Laboratory	**Bobbie Thoman** Walker Industries	**Jay Toups** Bioroot Energy Inc.	**Scott Tudman** Sweetwater Energy
René van der Merwe-Cuchens Bruks Rockwood	**Hank Venema** Prairie Climate Centre - IISD	**Timothy Volk** State University of New York College of Environmental Science and Forestry	**Dinko Vusic** University of Zagreb Faculty of Forestry
Michael Wang Argonne National Laboratory (ANL)	**Keith Webster** Iowa State University	**Chris Wiberg** Biomass Energy Lab (BEL), Pellet Fuels Institute	**Kevin Willerton** Navigant Consulting, Inc.
Irina Zirkler Yield Power Group			

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Overview

Financing Barriers to Bio-Projects in the US

One of the key challenges to the rate of growth of the bio-industry is that the risks associated with biomass supply chains are not well understood. While concerns about technology, construction and offtake have clear paths to resolution; at present there are no established protocols, standards, or recognized industry best practices for developers, investors, commercial lenders, insurance companies and rating agencies to utilize and rely upon to empirically demonstrate biomass supply chain risk.

The absence of a standardized and recognized approach means that the debt and capital markets are independently using inconsistent approaches and evaluation criteria, leading to unreliable assessments of bio-project risks. This results in significant project financing barriers for bio-projects and in millions of dollars of “financial-drag” on the projects that are eventually built.

Development of *BSCR Standards* is the first of a two-phase process to achieve the ultimate goal of creating efficiencies for the mainstream capital markets that help drive capital into bio-economy plant construction more rapidly and at a reduced cost.

Phase 1: The Biomass Supply Chain Risk Standards

By giving capital markets, credit agencies, commercial lenders and insurance companies a common validated approach when attempting to price feedstock risk, *BSCR Standards create efficiencies for the capital markets, accelerate existing bio-project development and attract additional national bio-industry development.*

These *BSCR Standard*s are organized into six *Risk Categories* that fully encompass biomass feedstock supply chain risk: *Supplier Risk*, *Competitor Risk*, *Supply Chain Risk*, *Feedstock Quality Risk*, *Feedstock Scale-Up Risk* and *Internal Organizational Risk*. Each *Risk Category* identifies specific *Risk Factors* (i.e. the pathways of risk within each *Category*), *Risk Indicators* (i.e. the markers of risk for each *Factor*), and establishes *Guidance* to point users to best-in-kind methods and tools to measure and mitigate feedstock risks.

The *Standards* have been developed with input from a stakeholder group of over 150 leading renewables companies and an Advisory Board with expertise aligned with various aspects of bio-feedstock risk.

Phase 2: Integrate a Risk Rating Framework and Scoring Protocols with BSCR Standards

Development of Phase 2 is currently being carried out by Ecostrat Inc. and Idaho National Labs (INL) with funding from The United States Department of Energy’s (USDOE) Bioenergy Technologies Office (BETO).

BSCR Standards are the necessary infrastructure for efficiently gathering data pertaining to all pathways of biomass feedstock risk; but without integration with a *risk rating system*, they are not independently sufficient to efficiently signal that risk to the capital markets. In order for the capital markets to make quick, efficient and effective decisions about biomass project risk, development of *an alphanumeric scoring and risk ratings framework (e.g., AA, A, BB, B-, etc.)* is required. Such a framework will efficiently translate all granular risk data and risk pathways identified by the *BSCR Standards*, into clear signals that the capital markets can utilize. The development of a signaling mechanism to translate project risks exposed by the *BSCR Standards* into the language of the capital markets is essential to achieving the goal of the *BSCR Standards*: driving capital flow to bio-projects.

Phase 2 will consist of development of a *Biomass Risk Rating Framework* based on the BSCR Standards (the "*BSCR Rating Framework*") to enable independent third-party evaluators to carry out *quantitative assessments* of feedstock risk of bio-project supply chains. The *BSCR Rating Framework* will consist of open ratings criteria, tools, transparent scoring protocols and standardized alphanumeric risk ratings. These components will bring together the risks and rankings from multiple *BSCR Risk Indicators* into a risk score for each *Risk Factor* and then into a single probabilistic expression of risk and rank for each *Risk Category*. Ultimately, a certification scheme will be developed so that clean fuel and other biomass projects can obtain independent verification, pre- and post-issuance, to ensure the ratings certification meets the requirements of the BSCR Standards.

Ecostrat has formed a *Risk Ratings Review Committee* of over 30 of the largest capital market players actively deploying over $50 billion of capital in the bio-sector—specifically, individuals from leading financial institutions, capital providers, investment banks, insurers and bio-economy industry organizations. The review committee members are a powerful endorsement of the value of biomass risk ratings to the capital markets and will provide essential input necessary to ground-truth draft iterations of the rating mechanisms and protocols, ensuring a valuable tool for the financial markets.

Biomass Risk Ratings Review Committee (selected members)

Combined with the *BSCR Standards*, an integrated *BSCR Rating Framework* will provide the capital markets with the tools needed to drive investment at the scale required by the *Bioeconomy Initiative*: *Implementation Framework* and other national bio-economy policies. It will do so by enabling investors and capital markets to efficiently quantify biomass feedstock risk, accurately price that risk, and prioritize investments with minimum feedstock risk.

Category 1.0: Supplier Risk

1.1 Risk Factor: Credit-Worthiness/Problematic Future Solvency of Supplier

1.1.1 PRODUCTION CAPACITY

Rationale	Supplier production capacity can be a strong indicator of long-term credit worthiness and future solvency. Higher production capacities can denote strength of operational elements, including cash flows, that are important to future solvency.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Supplier's monthly and annual production feedstock capacity along with any seasonal variations for at least 3 years 2. Whether the supplier's commitment exceeds current production capacity over any of the past 3 years, and if so, to what degree. **Reporting Recommendations** 1. Proponent should demonstrate understanding of equipment and infrastructure essential to production. 2. If supplier is an aggregator, it should demonstrate adequate control over sub-contractors and/or access to feedstock over suitable periods of time.
Guidance	**Guidance for Reporting Requirement 1** Written instruments validating the capacity and estimated production levels are preferred. Records of past production levels are good indicators of future production capacity (Crummett 2017). In the absence of the former, indicative confirmation of feedstock capacity can be derived indirectly from the quality and age of machinery, equipment, and facility size. Independent third-party confirmation by an expert in the field and previous experience in the region is preferred. Local procurement professionals with developed relationships in the region may have valuable insights about supplier's future production capacity. Feedback from competing markets should be solicited as to the quality, quantity, consistency and reliability of supply and any seasonal variations that may be relevant (however, it is acknowledged that this may be difficult to obtain due to competitive pressures). **Guidance for Reporting Requirement 2** Commitments of supply greater than current average production capacity may be viewed as higher risk than where contracted supply represents a fraction of current production. Commitments of less than 50% of a supplier's production capacity but more than 10% are deemed optimal. If supply commitment represents an increase versus current production capacity, then Proponent should validate the requirements for increased production in terms of capital, machinery, labor, logistics and raw feedstock availability. **Guidance for Reporting Recommendation 1** Age of equipment should be noted; newer equipment is generally more reliable than old. Equipment capacities should be consistent with supplier commitments. Proponent should understand: • Supplier's ability to fix equipment on site • Availability of key spare replacement parts • Supplier's capacity to afford replacement parts • Typical operational downtimes during replacements • Examples and explanations of supplier's previous downtimes

	Ground-truthing through on-site visits and/or independent third-party confirmation by an expert are preferred to understand supplier's feedstock production capacity.
Guidance Source	Bloomfield (2017, interview); Carollo (2017, interview); Crummett (2017, interview); Passmore (2017, interview)

1.2 Risk Factor: Supplier Contracts

1.2.1 CONTRACT PRICE VERSUS MARKET PRICE

Rationale	The value of a Proponent to its suppliers is directly related to how competitive it is relative to alternative markets for the feedstock the supplier provides. Even if a long-term contract is evidenced, if the contract price is materially below competing local markets (or even based on its cost relative to spot market prices), the supplier has less incentive to work with the Proponent in a constructive manner to resolve any operational or technical problems that arise, or to refrain from claiming a technical default under the contract when it is the supplier's interest to do so.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of supplier's contract price, and any other key terms that differ relative to competing markets. **Reporting Recommendations** 1. Proponent should demonstrate understanding of supplier's sensitivity to increases/decreases in price by competing markets for feedstock.
Guidance	**Guidance for Reporting Requirement 1** Copies of feedstock contracts with key competing markets should be obtained, if possible. Alternatively, anecdotal feedback from multiple local experts can serve as adequate validation.
Guidance Source	Solomon (2019, interview)

1.2.2 ATYPICAL FEEDSTOCK SPECIFICATIONS

Rationale	If required feedstock specifications differ from standard specifications required by competing markets in the region, then quality/quantity breaches are more likely. If specification is not typically produced in an area, supplier is less likely to deliver it.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Feedstock currently produced in the supply basin 2. The supplier's equipment and storage capacity should atypical feedstock specifications be required. **Reporting Recommendations** Proponent should demonstrate understanding of: 1. The proportion of quantity against supplier's total production should atypical feedstock specifications be required 2. Atypical feedstock specifications that are broader than typically accepted in a supply basin can function to significantly increase the stability of Proponent's supply chain.
Guidance	**Guidance for Reporting Requirement 1** This analysis shall be conducted so that the specifications widely produced by suppliers/required by competing markets, are known. If an atypical specification forms a large percentage of total production, risk of breach tends to be lower; if the percentage is a minor proportion then risk of breach may increase.

	Guidance for Reporting Requirement 2 This analysis should be examined to assess whether supplier can achieve specification consistently and at volume. **Guidance for Reporting Recommendation 1** Suppliers are more likely to default to the standard specification of feedstock they deliver to the majority of markets in the region; some suppliers will execute a contract that requires delivery of non-standard feedstock specifications. **Guidance for Reporting Recommendation 2** For example, a Proponent's specification for pulpwood that enables a forestry producer to enhance their bottom line by allowing a smaller radius of tree-length-top can result in preferential status versus alternative markets, thus providing greater resiliency.
Guidance Source	Solomon (2018, interview)

1.2.3 FAVORABILITY OF PAYMENT TERMS

Rationale	Payment terms that are less favorable than regional standard or those offered by competing markets can increase risk of breach—and vice versa.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of payment terms offered by competing markets; and if substantial difference is clear, it shall be justified. **Reporting Recommendations** 1. Proponent should demonstrate understanding of standard payment terms in the market, and the Proponent shall incorporate similar terms into supply contracts.
Guidance	**Guidance for Reporting Requirement 1** Feedback from local experts or a credible independent third-party is acceptable. **Guidance for Reporting Recommendation 1** For example, if typical practice among competitors is to pay suppliers on a weekly basis by electronic transfer, then 30-day payments terms by cheque may pose a risk to feedstock supply.
Guidance Source	Solomon (2018, interview)

1.2.4 FAVORABILITY OF DELIVERY TERMS

Rationale	Delivery terms that are less favorable than regional standard or those offered by competing markets can increase risk of breach—and vice versa.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of delivery terms offered by competing markets. If substantial difference is clear, it shall be justified.
Guidance	**Guidance for Reporting Requirement 1** Longer delivery windows, shorter wait-times to discharge trucks, and night-time/weekend delivery can all be significant incentives to suppliers, and can contribute to supply chain resiliency when feedstock is limited. Feedback from local experts or a credible independent third-party is acceptable for this data.
Guidance Source	Solomon (2018, interview)

1.2.5 CONTRACT "TAIL" LENGTH

Rationale	Feedstock supply under long-term contract may be considered lower risk than short-term contracts or spot agreements. Exceptions can be made in supply basins where long-term contracts are not traditional or feasible (e.g., pulpwood suppliers for pulp and paper mills), where the supply chain is robust and well established, or where long-term contracts could take away desired procurement flexibility or arbitrage opportunities.
Reporting	**Reporting Requirements** 1. Long-term contracts shall be signed with the supplier; or Proponent shall otherwise evidence support for long-term supply. **Reporting Recommendations** 1. Where long-term contracts are not feasible, Proponent shall demonstrate a short-term contract. Short-term contracts with long "tails" (i.e., required contract termination notices) are preferred. 2. Where short-term contracts (less than 3 years) are provided, autorenewals and long-tailed (more than 12 months) notice of termination are preferred. 3. Where neither a long- nor short-term contract is produced, a letter of intent (LOI) should be acquired from the supplier, signed, sufficiently detailed, dated recently and validated by an independent third-party.
Guidance	**Guidance for Reporting Requirement 1** Long-term contract means 3-10 years, although it is acknowledged the definition of "long-term" can vary between regions. Optimal contract lengths are unit-contingent with financing/debt terms (10-20 years). In most cases however, unit-contingent supply contracts may not be feasible to negotiate (with the exception of energy crops). In some biomass supply chains such as woody biomass where markets and supply chains are mature, long-term contracts may be neither required nor optimal. Where understanding and maturity of supply chains can be clearly demonstrated and where long-term contracts are not the norm, entering into long-term contracts may substantially increase feedstock cost without materially adding feedstock security or reliability (Parrish 2018). A mix between long-term and short-term contracts can be sufficient to demonstrate long-term feedstock availability if supply redundancy can be adequately demonstrated (Solomon 2018). Rob (2017) suggests that at least 40% of contracts should be long-term (3-10 years). **Agricultural Residues**. Passmore (2017) indicates that contracts for agricultural residues should be signed for at least 7 years. **Guidance for Reporting Recommendation 1** A long-tailed contract is one where the likelihood of renewal by the supplier is increased and the impact of termination on the Proponent is decreased by an automatic renewal clause structured in the following manner: after the end of each contract year, an additional 12 months is added to the tail-end of the contract, and where notice to terminate on the part of the supplier should be given in writing after the end of the then current term. Such a long-tailed contract can have the functional effect of making a short-term contract into a much longer-term supply arrangement. In the case of a 5-year long-tailed contract, if the supplier terminated in year 3, the Proponent would have roughly 5 full years to source replacement feedstock. **Guidance for Reporting Recommendation 3** Letters of intent (LOI)/memorandums of understanding (MOU) do not carry the security of firm, binding contracts. "Sufficiently detailed" means at minimum naming an intended term, quantity, quality specifications, price range and escalators, if any. "Dated recently" means within 12 months of the day of submission. "Validation" means confirmation by an independent third-party based upon direct feedback from the LOI signatory.

Guidance Source	Crummett (2017, interview); Carollo (interview); Robb (2017, interview); Hladik (2017, comment); Kirkwood (2018, comment)

1.2.6 CLARITY OF SAMPLE TESTING METHODS

Rationale	Inadequate or inconsistent sampling and testing methods may give results that do not accurately reflect specifications of delivered feedstock leading to disputes, disruptions and/or contract breach.
Reporting	**Reporting Requirements** The contract shall clearly define: 1. Sampling procedures 2. Regularity of testing 3. Size of samples taken 4. From where in the loads the samples should be taken 5. Testing standards used 6. Testing bodies/laboratories used. **Reporting Recommendations** 1. Sampling/testing procedures should be based on standardized protocols, or on methods mutually agreed upon by the Proponent and the supplier. If possible, a recognized industry sampling/testing standard shall be implemented. In Canada, CSA (Canadian Standards Association) standards, and in the, US ANSI or ASTM are all common and acceptable. In cases when industry standards are not available for particular feedstock type, the sampling/testing method shall be agreed upon between Proponent and supplier. 2. Proponent should control samples and sampling testing procedures. Third-parties may be used if required by both parties. 3. Time between when the samples are taken and when they are tested shall be specified in the contract. Ensure that retained samples cannot undergo material changes during retention. If so, testing shall be done by both parties on retained samples before such changes occur.
Guidance	**Guidance for Reporting Requirements 1-6** Hand-grab methods are discouraged due to collector bias. Contract should specify collection container to be used. Mechanical random sample grab methods are preferred. If samples are split, adequate mixing of sample should be ensured using a standardized testing procedure. Samples may be reduced before being sent to a lab (ASTM quartering method is recommended) and a portion may be retained by the supplier in case of dispute, if supplier requires it. 3-6-month retention of samples are standards. Visual inspection may be suitable for acceptance or rejection of load of feedstock, however if a load is rejected, Proponent should photographically record rejected material/or remove and retain a sample in case of dispute. **Agricultural Residues.** Nguyen (2018) suggests that a core sample should be deep (at least 24") and diagonal across several flakes in a corn stover bale. A perpendicular sample on a side of a bale will likely sample from two flakes at most. **Woody Biomass.** Waterfall method is recommended where three samples are collected from the beginning, middle and end of the discharge from the delivery vehicle, combined and reduced according to ASTM methodologies. If quality of samples can change between the time of sampling and the time of testing, Proponent should ensure that no material change can occur to sample during interim period such that the tested sample fails to accurately reflect the actual feedstock.

Guidance Source	Dujmovic (2019, feedback): Nguyen (2018, comment); Smith (2017, interview); Solomon (2018, interview); Spikes (2017, interview)

1.2.7 ACCURACY/SUITABILITY OF PRICE INDICES

Rationale	If indices or pricing benchmarks are used, such indices should accurately reflect the true cost of feedstock in the Proponent's supply basin.
Reporting	**Reporting Requirements** 1. Proponent shall ensure that suitable price indices are used to reflect anticipated feedstock cost variations over time. 2. Indices shall be appropriate for feedstock types, such that the index accurately reflects true cost of feedstock within the supply basin. 3. Indices shall be specific to the supply basin geography, such that the index accurately reflects true cost of feedstock within the supply basin. 4. Data underlying index shall be sufficiently granular, such that index accurately reflects true cost of feedstock within the supply basin.
Guidance	**Guidance for Reporting Requirement 1** Long-term risk of supply contracts increases where increased costs due to factors beyond supplier's control (e.g., diesel, inflation or labor cost) are not incorporated into the price with suitable indices. At minimum, Proponent shall determine whether diesel inflation adjusters are required. If increased costs are not indexed, then supplier margins can be squeezed and risk of breach over time increases. **Agricultural Residues and Energy Crops.** Oil price index can be important in relation to fertilizer cost fluctuations, as fertilizer price is correlated with oil price. If a contract does not reflect fertilizer cost fluctuations, in times of high fertilizer costs suppliers are prone to breaching (Altman 2018). **Guidance for Reporting Requirement 2** Proponent should ensure that the feedstock type definitions accurately reflect the object of the index. Small definitional differences can lead to discrepancies between actual feedstock and index. For example, a Wood Chip Index can track a composite price of a variety of fibre types such as clean chip, dirty chip (e.g., chip with bark) and whole-tree chip. If the Proponent feedstock is whole-tree chip, for example, the composite wood chip price may not be an accurate reflection of the price of the feedstock Indices should accurately reflect feedstock cost drivers for suppliers. Indices that adjust biomass cost according to the sale price of final products (e.g., increasing supplier's costs for wood fibre based on the Argus Index reflecting the sale price of wood pellets in Europe) may cause supplier margins to shrink and increase likelihood of dispute or breach. **Guidance for Reporting Requirement 3** Proponent should ensure that the geography of data points in index accurately reflect the object of the index. Biomass feedstock price can change substantially depending on region: geography and locality of granular data (that form basis of index) should accurately reflect where the feedstock is coming from. For example, an index that applies to an overly broad geographic area may misrepresent real changes in prices in the actual supply basin leading to increased risk of supplier breach. **Guidance for Reporting Requirement 4** Granularity of supporting data, meaning the quantity of data points used in the index, shall be statistically significant. An index based on insufficient data points will not accurately reflect the real cost on the ground.

	Currently there are no publicly available feedstock type-specific indices that are sufficiently granular to accurately indicate pricing of biomass on a local basis. In lieu of such an index, synthetic indices based on cost components of the feedstock supply chains may be applied. For example, since the cost of feedstock is to a large degree dependent on the cost of transportation, and cost of transportation is directly proportional to diesel and labor costs, as long as transport distance is capped, diesel price index and producer price index (PPI) may be sufficient proxies for forecasting changes to cost of biomass over time (Solomon 2018).
Guidance Source	Altman (2018, interview); Forest2Market (2019); Kaffka 2017 (review); Passmore (2017, interview); Solomon (2018, interview)

1.2.8 QUANTITY AND QUALITY OPTIONALITY

Rationale	Delivered quantity should be specified both annually and monthly. Proponent should have the ability to make limited up/down adjustments in feedstock delivery rates from suppliers. When Proponent has optionality over quantity from sources it enables resiliency when individual sources of supply fail.
Reporting	**Reporting Requirements** 1. Delivered quantity shall be specified no less frequently than monthly. 2. If there is an allowable variance in delivered quantities, and if such variance is at the supplier's discretion, sensitivities shall be run based on realistic worst-case delivery series. **Reporting Recommendations** 1. Delivered monthly quantities of feedstock should be at the Proponent's discretion in order to add resiliency to supply chain. +/- 5-15% at Proponent's discretion is recommended.
Guidance	**Guidance for Reporting Requirement 1** Consistency of feedstock delivery is important to supply chain resiliency. Delivery rate shall be specified daily, weekly or monthly as appropriate. If delivery rates per time-period are not specified, then suppliers may deliver feedstock when it is available, or when it is convenient or optimal for them to do so. Contracts that fail to specify monthly delivery dates leave Proponents with relatively low control over their supply chains since suppliers under annual contract can address delivery shortfalls in a particular period with additional deliveries in another period, and still comply with annual quantity obligations. This can result in supply surges when feedstock is abundant and delivery shortages when it is not. Inventories can be stressed, optionality reduced and Proponent's risk increased. **Guidance for Reporting Recommendation 1** The ability to adjust delivered quantities of feedstock from various suppliers gives a Proponent the ability to mitigate shortages in supply from one supplier by increasing deliveries from another. For example, if supplier A fails to meet delivery obligations for a certain month, the Proponent can increase deliveries from suppliers B, C, D and E in subsequent months to mitigate the impact. In this way, resiliency is increased and the impact of quantity failures from individual suppliers can be mitigated.
Guidance Source	Solomon (2018, interview); D. Smith (2019, feedback)

1.2.9 DAMAGE AND RECOURSE CLAUSES

Rationale	Damage clauses/recourse provisions can function to mitigate the impact of supplier breach. Even in cases where legal recourse is not practical (i.e., small suppliers) such clauses can still act as significant deterrent to breach. If circumstances change and it becomes in the supplier's interest to exit a contract, damage clauses/recourse can be a significant incentive for a supplier to meet its obligations in order to avoid penalty.
Reporting	**Reporting Requirements**

	1. Damage clauses shall be clearly stated in the contract if there is precedent for such clauses in the supply base. 2. Lack of specific damage clauses shall be adequately justified; and ratings scores shall not negatively reflect such absent clauses.
Guidance	**Guidance for Reporting Requirement 1** Damage clauses should reflect at minimum, the direct cost of replacing lost supply due to supplier breach in a timely period. For example, if a supplier fails to meet monthly delivery requirements, the Proponent may have the right to procure higher cost replacement feedstock within a certain period and deduct the difference from amounts owing to the supplier (Liew 2018). Damage clauses that make suppliers liable for indirect damages are significantly more challenging to implement. **Guidance for Reporting Requirement 2** It is important to note that damage clauses may not be feasible in many, and perhaps most cases due to lack of precedent. If damage clauses are not status quo in a particular feedstock basin, then imposition of such may not be possible or may impose significant economic burden. Specifically stated recourse provisions are not possible in some locales, since they can function as disincentives to suppliers. For example, in agricultural supply chains, contracts incorporating damages clauses that are too aggressive can be deemed offensive to farmers, and could create resentment among the wider supplier community (Hladik 2017).
Guidance Source	Altman et al. (2018); Hladik (2017, interview); Liew (2018, interview); Solomon (2018, interview)

1.2.10 FLEXIBILITY IN FEEDSTOCK SUPPLY QUANTITY

Rationale	Biomass suppliers are less likely to consistently meet quantity targets that are overly specific or fail to take into account natural fluctuations in supply capacity (e.g., seasonality). Providing contract flexibility tends to result in flexible supply chains (Jackson 2017).
Reporting	**Reporting Requirements** 1. Contracts terms shall take into account natural and reasonable variation in feedstock supply quantity, while still ensuring predictable and adequate feedstock supply. 2. If contracts allow for a range of quantity to be delivered at the supplier's discretion, then scenario planning of worst-case scenario impact on Proponent (i.e., supplier delivering minimum quantities) shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Contracts that specify a range of acceptable delivery quantities or a target "+/- X%" can decrease likelihood of breach. An analysis of feedstock production and quality against seasonality shall be conducted. Contracts shall include flexibility of supply based on seasonality. For example, moisture content is likely to change depending on the weather/season and moisture content contract specifications should reflect this. An analysis of variation in feedstock quality shall be conducted. Contracts shall include flexibility of feedstock quality based on this analysis. Penalty clauses that are regularly triggered can be seen as a backdoor method on the part of the Proponent for lowering feedstock costs and can foster resentment among suppliers. **Agricultural Residues.** Contracts should include provisions for a specific number of acres of production, but not yield. (Jackson 2017). **Energy Crops.** Studies regarding short-term contracts and wholesale contracts where suppliers are guaranteed a price per unit have been shown to be effective on high quality lands. Conversely, acreage contracts which guarantee suppliers a price per acre are best suited for low

	quality or unreliable lands. From the Proponent's viewpoint, wholesale contracts are better for the short-term, whereas acreage contracts are more effective in the long-term (Okwo & Thomas 2014).
Guidance Source	Jackson (2017, interview); Kirkwood (2018, comment); Okwo & Thomas (2014); O'Leary (2017, interview); Rainey (2017, interview); Smith (2017, interview); Tang & Tomlin (2008); D. Smith (2019, feedback)

1.2.11 SLIDING SCALES DRIVING FEEDSTOCK QUALITY

Rationale	Higher quality feedstock may be blended with lower quantity feedstock to increase overall quality. Higher quality feedstock delivered by one source of supply may mitigate risk of lower quality supply by others. For example, low moisture content feedstock can be blended with feedstock of higher moisture content to decrease overall moisture content. Certain suppliers may be able to provide higher quality feedstock than required but may not do so because there is no contractual incentive. Contracts should incorporate clauses which provide incentives to compensate suppliers for higher quality feedstock.
Reporting	**Reporting Requirements** 1. Proponent shall incorporate incentives or sliding scales into supply contracts, and if not appropriate, Proponent shall demonstrate why.
Guidance	**Guidance for Reporting Requirement 1** It is acknowledged that in many cases feedstock quantity will be unaffected by sliding scales as it is beyond suppliers' control, and sliding scales that provide for premiums based on higher quality may be unduly complicated and not appropriate in many situations. A sliding scale of increased payment for moisture, ash content or other key specifications less than X may, in certain cases, incentivize delivery of higher quality feedstock. Lack of precedent or negative feedback from suppliers in a supply basin shall be a suitable reason.
Guidance Source	Nguyen (2018, comment); Solomon (2019, interview)

1.2.12 INSURANCE POLICIES

Rationale	Supplier should have all types of insurance in sufficient quantities that are necessary to cover risks associated with operations.
Reporting	**Reporting Requirements** 1. Supplier shall provide Proponent a Certificate of Insurance evidencing suitable coverages and limits. **Reporting Recommendations** Supply agreements should include the following clauses: 1. Proponent should be named as an additional insured on the Commercial General Liability and Comprehensive Automobile Liability Insurance. 2. Policies should contain the unequivocal agreement on the part of the insurer to notify Proponent of the cancellation of, or any material change in, insurance coverage at least 30 days before the effective date of such cancellation or change. 3. Failure of the Proponent to object to the supplier's failure to provide a certificate or other evidence of the required insurance coverage, or object to any defect in such certificate or other evidence, should not be deemed a waiver of the supplier's obligation to furnish the insurance coverage.
Guidance	**Guidance for Reporting Requirement 1** Commercial General Liability Insurance shall be provided with a suitable limit per occurrence for: • Bodily/Personal Injury

	• Death and property damage • Worker's Compensation Insurance of the state where operations are being conducted and complying with any statutory requirements • Employer's Liability Insurance with a limit of $100,000 per occurrence.
Guidance Source	Solomon (2019, interview)

1.2.13 ASSIGNMENT, SUCCESSORS AND ASSIGNS

Rationale	Proponent should have the right to approve assignment of the supply contract by supplier to another party.
Reporting	**Reporting Requirements** Supply agreements shall include the following clauses: 1. Supplier shall not assign or transfer its interest in the supply agreement without the prior written consent of the Proponent, and such consent may be withheld at the sole discretion of the Proponent. 2. The Proponent shall be able to assign or transfer its interest in the supply agreement at any time without the consent of the supplier or other limitation. 3. Subject to the foregoing limitations, any agreement shall be binding upon, and inure to, the benefit of the successors and permitted assigns of the parties.
Guidance	
Guidance Source	

1.2.14 COMPLIANCE WITH LAWS

Rationale	Non-compliance by supplier can, in certain cases, present risk for Proponent.
Reporting	**Reporting Requirements** 1. Contract shall specify that supplier comply with and give notices required by all laws, ordinances, rules, regulations and lawful orders of public authorities with jurisdiction.
Guidance	
Guidance Source	

1.2.15 WARRANTIES

Rationale	Different biomass supply chains may require different supplier warranties.
Reporting	**Reporting Requirements** Supplier warranties shall contain, at minimum, the following clauses: 1. The materials to be supplied pursuant to the agreement shall be fit and sufficient for the purpose(s) intended 2. Supplier shall have title to the materials supplied and that the materials shall be free and clear of all liens, encumbrances and security interests 3. Such materials shall conform with the specifications, be merchantable, of good quality and free from defects 4. All warranties made in the agreement, together with service warranties and guarantees, shall run to the Proponent and its successors, assigns and tenants. **Reporting Recommendations** Supply agreements should include the follow clause: 1. In the event of any defect in the materials supplied or services performed under the agreement, Supplier shall replace or repair at its own cost or expense, and at the Proponent's discretion any damage suffered by the Proponent as a consequence of such defect. This provision shall not limit any other rights the Proponent might have at law or in equity.

Guidance	**Guidance for Reporting Recommendation 1** It is acknowledged that payment for damages cause by defect in the services and/or product supplied by the supplier may not be possible in many supply basins, particularly if it is not common practice among competing markets.
Guidance Source	

1.2.16 DETERMINATION OF FORCE MAJEURE EVENTS

Rationale	Force majeure clauses should not specify events which the supplier should be able to take steps to control. Supplier's may insert non-standard events as a force majeure that can serve as soft means of terminating supply contracts.
Reporting	**Reporting Requirements** 1. Proponent shall ensure that that if non-standard terms are included in the force majeure clause that such events are acceptable.
Guidance	**Guidance for Reporting Requirement 1** Non-standard terms include, but are not limited to, the following: • Change in market conditions • Loss of supply • Breach of supply by sub-contractors • Mechanical breakdown.
Guidance Source	

1.3 Risk Factor: Conflicts of Interest/Vested Interest with Competing Market

1.3.1 SUPPLIER'S DEPENDENCE ON, OR PREFERENCE FOR, COMPETING MARKETS

Rationale	Supplier may have a vested interest or preference to supply to specific competitors for biomass feedstock. Preferences may be due to historical, long-term, or personal relationships, less stringent feedstock quality requirements, more flexible operating hours by competing markets, or supplier's dependences on competing markets to accept or purchase other products/by-products. During periods of feedstock shortage such suppliers may be more likely to allocate the scarce supply to a competitor resulting in supply disruptions for the Proponent.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Knowledge of competing markets including, at minimum; approximate quantities, percentage of total supplier feedstock production and competing market's demand, and length of time supplied if supplier provides feedstock to competing markets 2. Knowledge of the quantity and relevance of the risk of leverage a competing market could exert on supplier if supplier provides feedstock and any other products or by-products to such competing markets. **Reporting Recommendations** 1. Proponent should demonstrate understanding of supplier's relationship with competing markets, if possible.
Guidance	**Guidance for Reporting Requirement 1** Relationships between traditional markets such as pulp and paper companies, and suppliers such as forestry producers or sawmills can be personal and span several generations.

	If for example, a sawmill produces both chips and bark as by-products and has traditionally provided both to a local papermill, and if it has contracted part of its chip supply to the Proponent, then in times of chip shortage, the papermill may be able to compel deliveries of chips by threatening to refuse to take supplier's bark, thereby leveraging supplier to breach obligations to Proponent. Anecdotal feedback from local experts can serve as adequate validation of vested interests. **Guidance for Reporting Recommendation 2** Anecdotal feedback from local experts can serve as adequate validation of vested interests.
Guidance Source	Hladik (2017, comment)

1.4 Risk Factor: Supplier Control Over Production and Transportation

1.4.1 OWNERSHIP OF EQUIPMENT

Rationale	In most cases, supplier which own or lease equipment for harvest, collection and processing feedstock are lower risk than those who are not. For example, third-party harvesting equipment may not be available when required. Short harvest windows may be missed if a farmer and contractor cannot schedule harvest times that are convenient and quantity shortages can result. However, in some circumstances reliance on third-party equipment to harvest or produce feedstock can decrease supply chain risk. For example, when harvesting agricultural residues such as corn stover, the use of a third-party company with standard equipment specializing in harvesting, collection and transportation may decrease quality variations (e.g., ash content) of final feedstock.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Supplier's equipment ownership 2. The risk of using a third-party's equipment in cases where the supplier does not own/lease equipment. **Requirements Recommendations** 1. Proponent should demonstrate precedent for the use of a third-party's harvesting, collection and transportation services.
Guidance	**Guidance for Reporting Recommendations 1-2** For example, a supply chain where a large number of suppliers have historically utilized third-parties with success may demonstrate lower risk.
Guidance Source	Brechbill et al. (2011); Hladik (2017, interview); Solomon (2018, interview)

1.4.2 OWNERSHIP OF TRANSPORTATION/LOGISTICS

Rationale	In most cases, suppliers that own or lease transportation equipment necessary to transport biomass from forest or field are lower risk than those who do not. However, in some circumstances, reliance on third-parties to transport biomass is common practice and does not contribute to risk.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of the risk of using third-parties, both in cases where supplier provides transportation but does not own/lease means of transportation, and in cases where transportation is provided by Proponent (or contracted to a third-party by Proponent). **Reporting Recommendations** 1. Proponent should demonstrate precedent for the use of a third-party's transportation services.

Guidance	**Guidance for Reporting Requirement 1** This should include an understanding of any scheduling issues with transportation company and supplier. **Guidance for Reporting Recommendation 1** For example, a supply chain where a large number of suppliers have historically utilized third-parties with success may demonstrate lower risk.
Guidance Source	Brechbill et al. (2011); Hladik (2017, interview); Solomon (2018, interview)

1.4.3 SUPPLIER AS AN AGGREGATOR OR BROKER

Rationale	Aggregators may effectively provide supply chain redundancy and eliminate risk and complexity of dealing with multiple sources of supply by combining supplies into a single master contact. Aggregators can add much needed stability into biomass supply basins by increasing offtake stability for both suppliers and markets. An aggregator can be a more reliable long-term offtake for suppliers by virtue of having multiple markets; and can be a more reliable long-term supplier for markets by virtue of having multiple suppliers. Further, when a single supplier breaches, the aggregator can source from another. Both aggregators and brokers are intermediaries. Aggregators consolidate and manage feedstock procurement from a number of smaller suppliers. Brokers tend to act as intermediaries between a single source of supply but brokers of multiple sources of feedstock are common. Aggregators act as principles in the supply of feedstock and assume the contractual obligations of a direct supplier; brokers do not. Definitional confusion between aggregators and brokers is common. If an aggregator does not assume supply risk of sub-contractors then they are more accurately deemed either a "procurement manager" or "broker". Aggregators add more value in terms of risk mitigation than other intermediaries. An aggregator premium should relate to the degree to which they are able to mitigate feedstock supply risks.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Intermediary's sources of supply 2. Intermediary's control over sub-contractors 3. How intermediary can mitigate risk of breach by individual sub-contractors 4. Ability of intermediary to warrant supply of feedstock.
Guidance	**Guidance for Reporting Requirement 1** Proponent should execute non-circumvent agreement if required by intermediary as precedent for source disclosure. **Guidance for Reporting Requirement 2** Provision of intermediary's contract terms with sub-contractors should be verified. However, it is acknowledged that most intermediaries will not disclose contract terms with sub-contractors as this would compel disclosure of margins. **Guidance for Reporting Requirement 3** Multiple sub-contractors can provide aggregators with redundancy in case of breach by one sub-contractor. Number of years in business and degree of activity in Proponent supply basin can provide aggregator with superior ability to mitigate risk of breach by sub-contractors.
Guidance Source	Solomon (2018, interview)

1.4.4 FEEDSTOCK AS A SECONDARY TRANSFORMATION

Rationale	A secondary transformation dependent upon the production of primary products; e.g., forest residues, corn stover, bark, or sawmill chips (unless from a dedicated chip mill) are all secondary transformations of a primary product. Risks are higher if feedstock is a secondary transformation of a primary, more valuable product. It may not be economical for suppliers to produce biomass on its own, in the absence of markets for the primary product. For example, a supplier may produce dimensional lumber as its primary product and wood chips as a by-product, therefore relying on the health of the housing market for production levels. If the demand for dimensional lumber drops, so can the availability of sawmill residues. In case of agricultural feedstocks such as corn stover, the feedstock is a by-product of a primary crop. Since the primary crop is significantly more lucrative than the residue, it will be a priority for the producer. If production of the primary crop requires resources be taken away from the production of secondary crop (e.g., in case of shorter harvesting windows due to weather), the secondary feedstock supply will suffer. In times of stretched resources, suppliers may also perceive harvesting and collection of the feedstock as a nuisance, potentially decreasing production levels. Understanding the economic drivers for suppliers' primary product can help gauge risk levels for secondary transformation biomass products.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Relationship between the primary product and the secondary transformation 2. Historical and projected market demand for supplier's primary product 3. The sensitivity of biomass feedstock production to demand fluctuations of the primary product.
Guidance	**Guidance for Reporting Requirement 1** Note how increases or decreases in production of the primary product affect the production levels of the secondary product. **Guidance for Reporting Requirements 2-3** In order to understand future biomass production levels, the demand for the primary product needs to be forecasted. Create a market analysis of the primary product determining the volatility of the production throughout different times of the year. Sensitivities to changes in demand should be modeled. If forecasts indicate an unstable demand for the primary product, long-term risk of biomass supply may be high. Finally, look for opportunities to increase the efficiency of the production of the secondary product (Kizha & Han 2016). Chip production levels in a sawmill are proportional, and therefore highly sensitive to, lumber production levels. For example, recent softwood tariffs imposed by the Federal government caused significant reduction in supply of lumber (and sawmills residues) in many Canadian mills. Similarly, agricultural by-products may be dependent on demand for a particular commodity, as agricultural commodities are typically replaced with others when market demand changes (e.g., wheat is replaced by rye). Create a market analysis of the primary product determining the volatility of the production throughout different times of the year. Contrast this analysis with a sensitivity analysis of the secondary product (biomass) to the primary product.
Guidance Source	Bloomfield (2017, interview); Krigstin (2017, interview); Kizha & Han 2016; Nguyen (2018, comment); O'Leary (2017, interview); Rainey (2017, interview); Rob (2017, interview); Solomon (2018, interview)

1.5 Risk Factor: Distance from the Proponent

1.5.1 DISTANCE FROM THE PROPONENT

Rationale	The greater the distance from a supplier to a plant, the more exposure it has to weather and fuel cost risks, and the greater the competitive pressure (to breach) that a closer competitor can exert.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. The maximum distance beyond which it becomes uneconomical or risky to transport feedstock 2. The geographical limits of supply, as well as how such limits may change over time and the cost/ risk that distance changes may result. **Reporting Recommendations** 1. Proponent should demonstrate understanding of the supplier's distance with respect to competitors, and the existing barriers that function to mitigate pressure to supply alterative short-haul markets.
Guidance	**Guidance for Reporting Requirement 1** If suppliers are handling transportation and providing feedstock FOB Proponent's site, then shorter delivery times will enable supplier to maximize margins. Generally, transport distances of 50-75 miles are considered viable, although this depends on the economics of the Proponents (Baylies 2017). **Guidance for Reporting Requirement 2** **Woody Biomass.** Suppliers will systematically be harvesting from geographically diverse locations.
Guidance Source	Baylies (2017, interview); Kaffka (2017, interview)

1.6 Risk Factor: Supplier's Experience

1.6.1 FUNDAMENTAL FEEDSTOCK PRODUCTION EXPERIENCE

Rationale	Risk is higher when a supplier has limited experience with planting/growing/harvesting/processing and/or collecting biomass. Limited experience may be common for stover or forest residue supply chains where farmers or forestry producers may have no previous experience. In cases where experience is lacking, Proponent should show that steps have been taken to ensure proper training, knowledge dissemination and monitoring.
Reporting	**Reporting Requirements** 1. In situations where suppliers are inexperienced with any area of biomass feedstock production, a comprehensive protocol that documents best practices and training shall be provided by the Proponent. **Reporting Recommendations** 1. Certain stages for biomass production should be outsourced to a specialized company if warranted.
Guidance	**Guidance for Reporting Requirement 1** **Energy Crops.** Mitchell (2017) proposes that regular field training in seeding should be carried out for energy crop production. **Guidance for Reporting Recommendation 1** An alternative to training is outsourcing aspects of production to specialized companies. This approach may be preferable where there is a large number of producers that need to be trained in

	biomass cultivation and harvesting. Outsourcing such activities to a specialized company can significantly lower the risk of quality issues, particularly homogeneity issues that can result from non-standard production techniques (Mitchell 2017).
Guidance Source	Mitchell (2017, interview)

1.6.2 PRODUCTION SCALE EXPERIENCE

Rationale	Scale-up entails risk. Risk is higher when a supplier has limited experience with the production of the quantity of feedstock required.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of whether supplier commitments exceed current outputs and if so, whether such commitments exceed capacity to produce with current equipment, manpower and supply/customer base.
Guidance	**Guidance for Reporting Requirement 1** Supplier's infrastructure (e.g., equipment, manpower, etc.) capabilities for additional capacity should be known, as well as their access to feedstock in relation to quantity targets. Proponent should also be aware of supplier's control of feedstock, and the barriers that may exist for them to access additional feedstock.
Guidance Source	Solomon (2019, interview)

1.7 Risk Factor: Supplier Harvesting/Collection/Processing Capacity

1.7.1 SUPPLIER'S EQUIPMENT EFFICIENCY

Rationale	Equipment efficiency significantly influences supplier's feedstock production capacity. Understanding supplier's equipment capability enables understanding of their ability to produce feedstock of suitable quality.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of the supplier's equipment efficiency, its potential improvement and whether it is sufficient for the Proponent's needs.
Guidance	**Guidance for Reporting Requirement 1** Conduct interviews with machine operators to understand equipment efficiency and average downtime. This information could be used to determine the risk of supply interruptions. Supplier's equipment, including its performance, should be evaluated by fuel procurement manager. In certain cases, contracts can specify equipment and maintenance standards (e.g., knife maintenance schedules for wood chippers). Additionally, exchange of information with machine operators or operational managers could increase equipment efficiency. If a supplier is informed from the start of the Proponent's needs, it can adjust its equipment and operations to suit the market (Abbas and Arnosti 2013). Track the effects different machineries have on different types of feedstocks. Refer to literature and studies regarding machinery and machinery efficiency (Lee et al. 2017).
Guidance Source	Abbas and Arnosti (2013); An and Searcy (2012); Dujmovic (2019, feedback); Lee et al. (2017)

1.8 Risk Factor: Supplier Motivation

1.8.1 FEEDSTOCK PRODUCTION PRIORITY

Rationale	When biomass feedstock is a secondary or non-core line of business, or when it is a by-product or a residual from a more valuable primary product, then suppliers may not put sufficient effort to consistently produce it. Risk of breach increases when production and/or delivery of feedstock compromises supplier's ability to make a primary product. When biomass feedstock is a by-product of another main higher margin or main product (e.g., corn stover (e.g., corn) or forest residues (e.g., pulpwood) supply may not be a top priority for a supplier.
Reporting	**Reporting Requirements** 1. Proponent shall determine relative importance of contracted feedstock production to supplier, especially whether production of feedstock is low margin or relatively small additional net profit. 2. **Agricultural Residues.** Proponent shall understand and model the harvesting window for the primary crop. If that harvesting window is small then the chance that the residue harvesting and collection will be ignored by the farmer increases.
Guidance	**Guidance for Reporting Requirement 1** Suppliers with a vested interest in continually supplying the Proponent have lower risk of breach. This can be achieved through providing partial ownership of the Proponent to the supplier or long-term bonuses based on a history of consistent supply. **Guidance for Reporting Requirement 2** This is a more common situation in secondary transformation agricultural feedstocks (e.g., stover) where the supplier may need to harvest in a particular window which, if missed, may make non-harvest much more likely. In cases where the production of the primary product interferes with the supplier's ability to produce a biomass by-product (e.g., stover), risk of non-supply may increase. Additionally, in times of stretched resources, suppliers may perceive harvesting and collection of the feedstock as nuisance, potentially decreasing production levels.
Guidance Source	Hladik (2017, interview); Mills (2017, interview); Muth (2017, interview); Carollo (2017, interview); Krigstin (2017, interview)

Category 2.0: Competitor Risk

2.1 Risk Factor: Competitor Influence on the Feedstock Market

2.1.1 COMPETITOR LOCATIONS AND GEOGRAPHICAL INFLUENCE ON THE MARKET

Rationale	Competitors' locations relative to a Proponent can affect the viability of procuring feedstock and the cost of that feedstock. Accurate and detailed competitor mapping provides an understanding of the geographical influence a competitor may have, including competitive advantages such as short-hauling.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate an understanding of the competitor's location relative to the Proponent, and its impact on feedstock supply. This shall include an evaluation of competitor's ability to short-haul the Proponent and otherwise exert pressure on local suppliers.
Guidance	**Guidance for Reporting Requirement 1** Standard industry practice suggests a thorough understanding of all competing markets of material size within a 2-3-hour drive-time of the Proponent (drive-time is preferred over

	distance). If Proponent's or competitor's feedstock is derived from distances greater than 2 hours, then an extension of the competition zone may be warranted. "Short-haul" refers to the advantage one biomass market may have over another due to proximity to a supplier and the pricing advantage less transport distance entails. Suppliers are often incented to provide material to the closest market, but such incentives could be overcome by other benefits (e.g., higher price, shorter payment terms, more favorable unloading hours, less waiting times, etc.) provided by the other, more distant markets. The closer market short-hauls the less proximate one. Map the competitor together with Proponent's suppliers to understand the competitor's ability to affect supply. Competitors located in close proximity to the Proponent may drive feedstock cost and put pressure to breach on Proponent's contracted suppliers, especially during times of shortage.
Guidance Source	Crummett (2017, interview); Solomon (2018, interview)

2.1.2 HISTORICAL FLUCTUATION OF QUANTITY USED

Rationale	Clear understanding of key competitors' consumption of each type of feedstock utilized by the Proponent is essential to quantifying the risks associated with each competitor. Understanding historical trends of feedstock utilization can provide valuable information about feedstock price elasticity during shortages, and insight into events that may impact future supply conditions. It can enable more accurate estimates of the sensitivity of feedstock availability to potential future consumption levels or to the impact of external events (e.g., weather events, structural economic changes, seasonality, or policy change).
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Current key competitor intake quantity for each type of feedstock used by the competitor 2. Current key competitor intake quantity for each type of linked feedstock. **Reporting Recommendations** Proponent should demonstrate understanding of: 1. Historical utilization of each type for feedstock used by the Proponent 2. Historical competitor intake quantity for each type of linked feedstock.
Guidance	**Guidance for Reporting Requirement 1** Not all competitors will have the same relevance to a Proponent. "Key" or "major" competitors are generally characterized by intake of similar feedstock in material quantities, and are located within 100 miles of the Proponent. "Linked feedstock" refers to feedstock not used by the Proponent but used by competing markets, and which could be used by competing markets to exert influence on a supplier. For example, during times of shortage a pulp and paper mill that utilized both chips and bark could refuse to accept a supplier's bark unless it supplied the chips otherwise being contracted to the Proponent. At minimum, data shall, for every type of feedstock utilized by the Proponent, include feedstock category and description for annual and monthly quantities. Published/public data is preferred but often unavailable. Third-party feedback is acceptable if triangulated. **Guidance for Reporting Recommendation 1** "Historical information" shall refer to data covering at least 3 years. 5 years is preferable.

	Most accurate information about competitors' feedstock consumption often comes from suppliers. Developing good initial relationships with suppliers can provide access to valuable information about competitors. **Guidance for Reporting Recommendation 2** A credible third-party company should be engaged to collect and/or verify the competitor's feedstock quality specifications.
Guidance Source	Abt (2018, interview); Baylies (2017, interview); Crummett (2017, interview)

2.1.3 COMPETITOR PRICING AND PRICE SENSITIVITY

Rationale	Understanding how much competitors pay for different feedstock types is an essential step to determining competitiveness of Proponent. Historical prices paid by competitors provide insight into their procurement behaviors and ability/willingness to pay premiums for feedstock and expert pressure on Proponent's suppliers during times of feedstock shortage. Competitors that have an ability to offer higher prices for feedstock during feedstock shortages can pose significant risks to Proponent. Knowledge of competitor pricing and price sensitivity is also an essential prerequisite to formulating a feedstock cost curve which can enable predictions of feedstock redundancy; i.e., how much feedstock could become available at different pricing levels (*see Category 3–Supply Chain Risk 3.1.3*).
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Current price paid by competitors for feedstocks used by Proponent 2. Historical feedstock price paid by the competitor. If significant price fluctuation has occurred, then Proponent shall demonstrate understanding of factors driving such fluctuation. 3. The market for competitors' end products and any relationship between this market and the ability of competitor to drive feedstock price over time. **Reporting Recommendations** Proponent should demonstrate understanding of: 1. Current price paid by competitors for linked feedstocks 2. Competitor's sensitivity to price increases 3. Competitor's track record of driving feedstock cost during periods of shortage 4. Payment terms 5. Payment history.
Guidance	**Guidance for Reporting Requirement 1** If possible, pricing information should be acquired directly from the competitor or from published area data. However, competitors are often reluctant to supply such information. Use of a credible third-party to validate competitor feedstock price data is acceptable. **Guidance for Reporting Requirement 3** Competitors' demand for feedstock and the maximum price they can pay for it may depend on the markets for their final product. For example, a pulp and paper mill's demand for feedstock depends on the paper market. It is important to understand competitors' end-markets to understand their likelihood of expanding operations and impacting feedstock availability and price. Pass-throughs for feedstock costs are rare but it is important to understand whether this is an advantage a competitor has. A wood-to-power plant with a feedstock pass-through contract with its buyer is able to drive costs in times of shortage and may thereby constitute significant risk for a Proponent. Anecdotal feedback from local supplier or a credible third-party expert may be useful in obtaining this kind of information.

	Guidance for Reporting Recommendation 1 Third-party reports can be used to obtain historical feedstock pricing data; reliability can be acceptable if confirmed by at least three independent sources (i.e., triangulation). Suppliers can serve as sources of data validation. **Guidance for Reporting Recommendation 2** Understanding competitors' price sensitivity can help the Proponent understand whether it is in a favorable position to acquire feedstock at times of low supply. The sale price/value or margins of a competitor (e.g., pulp and paper) may enable it to pay higher buy prices in order to capture scarce feedstock during times of shortage (Solomon 2019). Offtake agreement that allow pass-throughs for increases in feedstock costs (e.g., Power Purchase Agreements (PPAs)) may create a non-level playing field in times of feedstock shortage. Suppliers should be contacted to inquire about the competitor's ability to pay higher prices during times of shortage (Tudmand & Hvisdas 2018). A credible third-party should be engaged to collect/validate information. **Guidance for Reporting Recommendation 4** It is important to gauge Proponent's payment terms relative to competing markets. Faster payment terms can constitute a significant advantage where pricing is comparable. **Guidance for Reporting Recommendation 5** It is important to gauge competitors' payment history, in particular instances over the past 3-5 years of non-payment due to insolvencies or restructuring.
Guidance Source	Baylies (2017, interview); Crummett (2017, interview); Lowitt (2013); O'Leary (2017, interview); Tudmand & Hvisdas (2018)

2.1.4 IMPACTS OF FUTURE DEMAND ON FEEDSTOCK AVAILABILITY AND PRICE

Rationale	Future competitors for feedstock, or expansion of feedstock demand by current competitors, can cause feedstock market disruption. Even before new competitors become operational, high interest in a supply basin can make suppliers overconfident, leading to a supplier-controlled market where short-term contracting becomes the norm and supply chain reliability is compromised for the Proponent. Once operational, new competitors increase demand on feedstock, potentially lowering availability and increasing cost. Existing competitors may seek to expand operations, increasing consumption of feedstock.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Forecasted new demand on feedstock availability and price; impact of any proposed competitors or ones currently under construction (including currently operating competitors that have indicated potential expansion) 2. Non-forecasted but potential new demand on feedstock availability. **Reporting Recommendations** 1. Proponent should demonstrate understanding of conditions in which a competitor is likely to expand operations and/or barriers to entry for new competitors for feedstock.
Guidance	**Guidance for Reporting Requirement 1** Information about expansions or competitors currently under construction can often be found through press releases and local economic development agencies, or through third-party experts and existing suppliers. Information about proposed Proponents can be harder to find; however, online research, press releases and conversations with experts and suppliers can provide sufficient information for analysis. **Guidance for Reporting Recommendation 1** Modelling the impact of potential future expansion plans of competitors, and of market conditions that can result in competitors' desire to expand (e.g., a surge in the housing market, increased demand for renewable natural gas (RNG), or a subsidy for green power) are important for correctly forecasting future feedstock availability and price.
Guidance Source	O'Leary (2017, interview)

2.1.5 SUPPLY INFLUENCE OF COMPETITOR

Rationale	In some cases, competitors may be able to exert high degrees of pressure over local suppliers, effectively enabling them to control feedstock, especially during times of shortage. This control can derive from long previous relationships between suppliers and competitors. It can also result from verbal or "understood" agreements, or a competitor being able to assist suppliers in times of surplus by maintaining large inventories which enable suppliers to continue supplying when other markets impose quotas. Understanding and planning around such soft risk factors is important. If such relationships exist in the Proponent's procurement area, they may indicate increased risk of feedstock shortage or pricing changes.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. The proportion of supply that the competitor can control 2. Historical occurrences where a competitor exerted control over supply.
Guidance	**Guidance for Reporting Requirement 1** Suppliers are the most reliable source of information for gauging whether the competitor can exert sufficient pressure on feedstock supply to control it.

	Agricultural Residue and Energy Crop. Farmers may be incented into changing the type of feedstock grown if an alternative type is more profitable. Proponent should gauge the risk of forward cropping changes.
Guidance Source	

2.1.6 TEMPORARY MARKET-DRIVEN MARKETS

Rationale	Alternative, non-traditional, market-driven competitors for feedstock can drive feedstock demand in unusual circumstances. A Proponent using corn stover as a feedstock, for example, would not typically compete with higher-end animal feed markets due to quality issues. However, in times of significant hay shortage (e.g., during drought), farmers use corn stover in place of hay, driving the price of feedstock and decreasing availability for bio-projects (Bergtold 2018).
Reporting	**Reporting Requirements** 1. Any alternative, non-traditional and market-driven markets for feedstock shall be identified, and the likelihood and impact of these markets upon Proponent shall be assessed.
Guidance	
Guidance Source	Bergtold (2018, interview)

2.2 Risk Factor: Competitors' Competitive Advantage

2.2.1 RELATIVE INVENTORY CAPACITY

Rationale	The more inventory a biomass facility is able to store, the more competitively it can behave on the market. Ability to store large inventories allows biomass Proponents to purchase inventory when the prices are low, giving it an economic advantage. Additionally, the ability to store inventory during feedstock supply surpluses enables competitor to continue to intake feedstock when the Proponent (with lesser inventory capacity) may be forced to put suppliers on quota. Larger investor capacity thereby creates supplier loyalty and this can increase reliability and decrease risk.
Reporting	**Reporting Requirements** For each key competitor, Proponent shall demonstrate understanding of: 1. Quantities of feedstock inventory that can be stored by competitors 2. Competitive advantage due to high inventory potential.
Guidance	**Guidance for Reporting Requirement 1** The quantity of stored inventory depends not only on available space in the yard, but also on the tolerance for feedstock quality. For example, feedstock stored for long periods can lose some of its calorific value. An assessment of land currently used for storage, stacking equipment and pile height restrictions, multiplied by that period of time until degeneration can enable a high-level determination of a competitor's feedstock inventory potential.
Guidance Source	Rainey (2017, interview)

2.2.2 RELATIVE ACCESSIBILITY/DELIVERY HOURS AND WAIT TIMES

Rationale	The value attributed by suppliers to local markets is often directly related to the degree of flexibility the market provides in terms of delivery hours, and the more efficiently discharge can occur.
Reporting	**Reporting Requirements** For each key competitor, Proponent shall assess: 1. Discharge hours 2. Average and maximum wait times to discharge

	3. Potential accessibility issues.
Guidance	**Guidance for Reporting Requirement 1** Suppliers are likely to favor end-markets that provide more logistical convenience. **Guidance for Reporting Requirement 2** For example, if competitor's price and transport distance are similar but wait time to discharge averages 2 hours versus 30 minutes for the Proponent, this would be a significant competitive advantage for the Proponent which could function to materially decrease risk. **Guidance for Reporting Requirement 3** Accessibility issues include road access, quality of yard conditions (e.g., paved, gravel or dirt), traffic and seasonal weight restrictions.
Guidance Source	

2.2.3 RELATIVE SPECIFICATION ADVANTAGES

Rationale	When choosing a market, suppliers not only look at price, but also at relative quality requirements or specifications. It is important to understand a competitor's feedstock quality specifications in order to accurately quantify the risk that a competitor can exert on the Proponent's supply chain.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of the specifications for each category of competing feedstock relative to that of the Proponent, and shall assess the impact of any differences.
Guidance	**Guidance for Reporting Requirement 1** For example, if a potential competitor has a tighter quality specification than the Proponent, then it may not be a strong competitor for feedstock. On the other hand, a looser specification (e.g., higher allowable fines, contamination levels, ash, or sizing) may provide a competitor with a significant competitive advantage.
Guidance Source	Cook (2018, interview); Marsollek (2018, interview); Rainey (2017, interview)

2.2.4 DEMAND FOR COMPETITORS' PRODUCTS

Rationale	Increased demand for competitor's product can cause an increased demand for feedstock by the competitor, given the competitor can increase its production capacity easily. For example, an increased demand for biofuels due to a clean fuels policy can cause increased biofuel production by the competitor, thereby increasing demand for feedstock.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of the market for competitors' products and its potential for increased demand.
Guidance	
Guidance Source	Khanna et al. (2011); Parrish (2018, interview)

Category 3.0: Supply Chain Risk

3.1 Risk Factor: Feedstock Availability

3.1.1 BIOMASS AVAILABILITY MULTIPLE (BAM)

Rationale	Biomass Availability Multiple (BAM) indicates the degree of redundancy in a Proponent's supply chain. BAM is the ratio of biomass feedstock available to a project, at costs, timing, and in quality feasible for the Proponent, divided by the project's feedstock requirements. BAM is a strong indicator of supply chain resilience when stressed by supply shortage and/or supplier breach.
Reporting	**Reporting Requirements** 1. The Proponent shall understand the Biomass Availability Multiple (BAM) for its project. 2. If more than one feedstock type is used, a separate BAM shall be understood for each feedstock type. 3. BAM shall be calculated based on feedstock which is realistically accessible for use by the Project ("Available Biomass"), rather than on theoretically available/modelled feedstock ("Produced Biomass"). 4. BAM shall be calculated within a band of economically feasible pricing as defined by the Proponent. Biomass feedstock that is available to a project shall be calculated using maximum price required to maintain ongoing operations and service financial covenants. 5. BAM shall be calculated using feedstock that is available to the Proponent in a timely manner so as to prevent operational disruption. 6. Quality of redundant feedstock used in the calculation of BAM shall be useable by the Proponent. 7. BAM shall be calculated at a sufficiently detailed geographic resolution. **Reporting Recommendations** 1. Demonstrated BAM should be at minimum 1.5, and preferably > 2.0.
Guidance	**Guidance for Reporting Requirement 1** Geographic area for redundant feedstock used in the calculation of BAM should be the maximum drive-time distance outside of which sourcing drives feedstock cost beyond economic feasibility for the Proponent. This is the feedstock procurement "red-line" price at which a Proponent is no longer able to maintain operations, or will breach a financial covenant or warranty. BAM cannot be verified or evidenced by contract as, by definition, BAM is the amount of feedstock available to the Proponent above and beyond that which is needed to meet quantitative requirements. In rare cases however, a Proponent may execute written option agreements giving it the right to procure feedstock if and when required. Such options can be with a contracted supplier (to purchase additional quantities as required) or with new suppliers, and can be powerful supporters of a Proponent's BAM. Utility of BAM is less pronounced for operating projects than for greenfield projects. **Guidance for Reporting Requirement 3** Hypothetical or derivative estimates of produced feedstock can provide theoretical indication of BAM. But to understand quantities of feedstock that are actually available, supportive granular data derived from real sources of supply regarding willingness or commitment level to provide feedstock to the Proponent are vastly superior indicators in terms of predictive accuracy. Just because feedstock is produced proximate to a Proponent does not mean it is necessarily available to that Proponent. A sawmill may generate 20,000 tons of chips per year, but may only have 2000 tons available for purchase—or none at all. BAM should be established using past and current market availability and trend information from established and defensible data sources. Contributing to this data can be the growth to drain

(GTD) or growth removal ratio (GRR) which can serve as an indicator for assessing the long-term availability of sustainable woody feedstock from forests.

In the US, Forest Inventory Analysis (FIA) program by USDA Forest Service is the best source of forest inventory data.

In Canada, forest inventory data (including harvest licenses, biomass removals, remaining residues etc.) are collected and disseminated by provincial forestry departments (Gunn 2019). Also, Canada's National Forest Inventory is one source which can be used to acquire forest inventory data necessary to estimate GTD and GRR.

Feedstock extraction rates can vary in different locations. Regional policy can dictate the quantity of forest residues to be left in the forest after harvesting. Suppliers may choose to leave large quantities of forest or agricultural residues on land, either for environmental or economic reasons; agricultural residues provide nutrients for agricultural fields, and farmers leave portions of residue as fertilizer. Primary and secondary research should be conducted indicating regional feedstock extraction rates.

Thiffault et. al. (2014) analyzed the recovery rate of forest residues based on data from temperate and boreal forests from around the world. They determined that the average recovery rate was about 52.2% depending on the local policies and the type of harvesting (e.g., stem-only, bundling, whole-tree harvesting, etc.). In non-Nordic countries, the recovery rate of forest residues ranged from 35.6-60.7% depending on the recovery method.

Agricultural Residues and Energy Crops. Availability of agricultural residues can be assessed through grain yields. The following are accepted conversion ratios (list provided by Gunn 2019):

- Corn: 1 (Sokhansanj et al. 2006)
- Beans: 1 (Nelson et al. 2004)
- Wheat: 1.5 (Nelson et al. 2004)
- Grass: 1 (Sokhansanj et al. 2006)
- Barley: 1.5 (Penn State Agronomy Guide 2019-2020)
- Soybean: 1 (Penn State Agronomy Guide 2019-2020)
- Oats: 1 (Penn State Agronomy Guide 2019-2020)
- Sunflower: 3 (Helwig et al. 2002)

Additionally, National Agricultural Statistics Service (NASS) keeps track of annual, county-level crop production statistics, which can be used to estimate availability of energy crops and grain crop residues.

Guidance for Reporting Requirement 4

The numerator of the BAM shall be constrained relevant to the maximum price that the Proponent can pay for feedstock. For example, if a Proponent can consistently remain operational and service financial covenants at up to $39 per ton FOB for pulpwood, then BAM should be calculated based on the amount of feedstock that is available at that price but no more.

Guidance for Reporting Requirement 5

It is important to understand the timeline at which additional biomass may be available to a project. If additional feedstock is eventually available to a project but not within a timeframe that prevents operational disruption to the Proponent, then it should not be included in the BAM calculation.

Guidance for Reporting Requirement 6

Quality of feedstock used in calculation of the BAM shall be fungible with primary feedstock. The BAM should not be artificially inflated by the addition of sub-standard feedstock simply because it is "available". The numerator of the BAM should reflect availability of feedstock where the usability is demonstrated by the Proponent.

Guidance for Reporting Requirements 7

	Where possible, the Proponent should use data at higher than jurisdictional boundary (i.e., county, province/state, forest management unit) resolution. An example of such dataset is the Manitoba Bioeconomy Atlas. The Atlas uses fusion of AAFC Crop Inventory (30 m), Crop Insurance Yield ratios and Statistics Canada sector data to assess high-resolution crop production (Gunn 2019). **Guidance for Reporting Recommendation 1** If BAM is based on derivative or secondary data, and the numerator is derived from a high-level estimate of feedstock "produced" in the supply basin as opposed to what is likely to be actually "available" to the Proponent, then it is recommended that BAM should be higher than 2 in order to accurately indicate supply chain redundancy. It should be noted however, that there are successful existing projects with BAMs as low as 1.5. While bigger tends to be better, there is no optimal BAM; an acceptable BAM depends on creditors' tolerance of risk. **Agricultural Residues.** In general, agricultural residue producers have few markets for their residue. The lack of competition for agricultural residue means that a high BAM is not necessary for low-risk supply (Hladik 2017). Note that Regenerative Agricultural Practices encourage minimal tillage to improve soil health which leads some producers to minimize residue removal. The Proponent shall take existing agricultural practices into account when making a case for residue removal. Current research can be used for such argument, particularly that long-term research shows most residue can be removed with no adverse impacts (Gunn 2019). An example of such research can be found in Lafond et al. (2012).
Guidance Source	Bloomfield (2017, interview); Carollo (2017, interview); Golecha & Gan (2016); Hladik (2017, interview); James et al. (2012); Lewandowski (2018, interview); Solomon (2019 interview); Spikes (2017, interview); Texas Forest Service (2006); Thiffault et al. (2014); Gunn (2019, feedback); Sokhansanj et al. (2006); Nelson et al. (2004); Penn State Agronomy Guide (2019-2020); Helwig et al. 2002; Lafond et al. (2012)

3.1.2 IMPACT OF INCREASED UTILIZATION OF FEEDSTOCK

Rationale	Feedstock utilization in a supply basin can change over time. Existing consumers of feedstock can expand operations or new facilities can enter the market. Increased utilization puts additional pressure on feedstock and can lead to higher prices, feedstock disruptions, shortages or supplier breach.
Reporting	**Reporting Requirements** 1. Increased feedstock utilization scenarios shall be modeled to determine impact of additional demand on Proponent feedstock supply and/or cost. Sensitivity analysis showing impact of increased feedstock utilization on Proponent shall be conducted. 2. Modeled demand scenarios should be realistic, conservative and justified. 3. If feedstock is a secondary transformation (e.g., forest residue) then the feedstock utilization scenarios shall be run based on the changes in demand for the primary product. **Reporting Recommendations** 1. Scenarios reflecting potential increase in feedstock production in the long-term due to increased demand for feedstock should be considered.
Guidance	**Guidance for Reporting Requirement 1** Increases in feedstock utilization by existing or future competitors can reduce overall availability of feedstock and drive price. Scenario-based modelling should incorporate known information about competitors' historical and planned expansions, as well as assumptions based on anecdotal knowledge of the market and potential expansion. The Sub-Regional Timber Supply (SRTS 2018) model can predict utilization of supply of forest-derived feedstocks under various demand models (Abt 2018). **Guidance for Reporting Requirement 2**

	Error bounds on models used to make forecasts shall be available for specific locations of interest and different times of the year so that predictions are accompanied by confidence intervals (Calvert 2011). **Guidance for Reporting Recommendation 1** Modelling should be conducted using geomatics (i.e., Geographic Information Systems) to account for spatial availability of feedstock. Not all scenarios of increased feedstock utilization by competitors will have exclusively net negative results over the long-term. Increased feedstock utilization by competition, while detrimental in the short-run, can actually function to increase supply, particularly in the long term, as supply can increase to meet demand if infrastructure is the constraint. Economic models are available (e.g., Lamers et al. 2018) to estimate long-term impacts/benefits from increased utilization by competition and the market response and stabilization by subsequent increases in production.
Guidance Source	Abt (2018, interview); Carollo (2017, interview); Calvert (2011); Lamers et al. (2018); SRTS (2018)

3.1.3 FEEDSTOCK SUPPLY CURVE/MARGINAL COST CURVE

Rationale	The greater the feasible transport distance, the more feedstock is accessible to the Proponent, but at a higher delivered cost. The feedstock supply curve, sometimes referred to as the marginal cost curve, is a function of feedstock availability over its cost which is primarily, but not exclusively, a function of distance. The feedstock supply curve is used to determine the availability of redundant feedstock at various price points, and the cost of replacing feedstock with substitutes located at different distances. Feedstock cost curves are useful in determining supply chain resilience; they provide information about the cost of feedstock availability in times of supply disturbance. Biomass supply chains are prone to supply disturbances over time; suppliers can become insolvent or weather events can temporarily disrupt feedstock availability. When a disturbance occurs, the Proponent may need to source replacement feedstock from different suppliers at different locations and costs. A biomass supply curve indicates quantities of feedstock available at various price levels from suppliers generally located further away than core suppliers.
Reporting	**Reporting Requirements** 1. A supply curve representing feedstock availability over price and distance shall be developed and any significant inflection points shall be adequately explained. 2. If more than one feedstock type is used, then a separate cost curve shall be developed for each feedstock type. 3. Feedstock cost curve shall incorporate realistic quantities of feedstock actually available to the Proponent. Feedstock cost curve shall be calculated based on feedstock that is realistically accessible for use by the Proponent ("Available Biomass") rather than on theoretically available/modelled feedstock ("Produced Biomass"). 4. Feedstock cost curve shall be calculated within a band of economically feasible pricing as defined by the Proponent. Feedstock that is available to a project shall be calculated using maximum price required to maintain ongoing operations and service financial covenants. 5. Feedstock cost curve shall be calculated using feedstock available to the Proponent that is available in a timely manner so as to prevent operational disruption. 6. Quality of redundant feedstock used in feedstock cost curve shall be useable by the Proponent. **Reporting Recommendations** 1. Proponent should assess economic burden on the project procuring redundant feedstock (from larger distances) under low, medium and high supply chain stress scenarios.
Guidance	**Guidance for Reporting Requirement 1-6** Same as for 3.1.1
Guidance Source	Solomon (2019, interview)

3.1.4 SEASONAL FEEDSTOCK SUPPLY VARIATION

Rationale	Biomass supply can present significant seasonal supply variations. Seasonal supply variations combined with limitations associated with longer-distance transportation and storage can lead to regional biomass supply imbalances (Golecha & Gan 2016) and can manifest in shortages and higher costs for Proponents.
Reporting	**Reporting Requirements** 1. Understanding of seasonal feedstock supply variation shall be demonstrated for each feedstock type. **Reporting Recommendations** 1. A mitigation plan to lower the risk of seasonal feedstock supply variation should be demonstrated through one or more of the following methods: • Inventory • Feedstock substitution • Feedstock supply optimization models.
Guidance	**Guidance for Reporting Recommendation 1** Seasonal feedstock availability is more prevalent in agricultural supply chains (i.e., agricultural residues and energy crops) than in woody biomass supply chains. Optimization models can help quantify the risks of seasonal supply variation. An example of an optimization model for biomass availability can be found in Golecha & Gan (2016). Proponent should assess the ability of feedstock inventory to meet demands during non-productive seasons. Strategic inventory and storage planning can sustain a steady supply of feedstock to the Proponent. Primary feedstock may be substituted with secondary feedstocks in times of seasonal feedstock shortage. If secondary feedstocks are being utilized then fungibility with primary feedstock should be demonstrated.
Guidance Source	Ba et al. (2016); Carollo (2017, interview); Gebresslasse et al. (2012), Golecha & Gan (2016); Rob (2017, interview); D. Smith (2019, feedback)

3.1.5 YEAR-TO-YEAR VARIATION IN FEEDSTOCK AVAILABILITY

Rationale	Biomass can have significant year-to-year supply variations due to variability in yield from biomass harvesting operations, particularly with agricultural biomass.
Reporting	**Reporting Requirements** 1. Projected year-to-year feedstock supply variation shall be modeled for each feedstock type. 2. Strategies to counteract estimates of year-to-year supply variation shall be developed. **Reporting Recommendations** 1. **Agricultural Biomass.** Proponent should obtain historical data on yields of feedstock in the supply basin to make a determination of variability. If historical data are not available for predicting future yields, mathematical models may be used. 2. **Woody Biomass.** Models used to demonstrate yield variability should be based on species, region and stand density of timber harvest operations.
Guidance	**Guidance for Reporting Requirement 1** Variability manifests in both space and time. Spatial variability can also be judged based on physical and topographic features. For example, a region consisting of large variations in ground surface elevations will have high potential for soil erosion. When this region also has soils that can be easily eroded during precipitation events, the site would be at an increased risk for insufficient production.

	Variability in yields of crop residue can be attributed to several factors including climate, soil, management practices and pests. The best evaluations of these factors are made at more macro-scales. Yield variability could also be high in regions consisting of flat terrain if soil properties, climate conditions or management practices are not suitable for the crops being studied. **Agricultural Biomass.** Models based on machine learning, mechanistic plant growth approaches and Bayesian techniques are available to capture variabilities on multiple scales (e.g., at county or regional scales) and make spatially-explicit yield predictions (Newlands and Townley-Smith 2010; Phys-Org 2017; Jeong et al. 2016; Jiang et al. 2017; FAO 2017; Chawla et al. 2016; PNNL 2017; Busby et al. 2017; Jager et al. 2010). While many more approaches exist to predict yields, there are no directly usable models that are available in the public domain to estimate energy crop and crop-residue yields at the farm or field scale. Depending on the crop of interest and location, a more advanced literature analysis is a prudent way of obtaining best estimates of energy crop or crop-residue yields. It should also be noted that new methods based on artificial intelligence and machine learning techniques are being developed and should be explored through a review of the relevant literature. Because of the dependency on multiple variables, it is recommended that a project in need of such data approach academic or research institutions to obtain defensible predictions of energy crop and crop residue yields based on applicable locations and time periods. It will take considerable time and resources for a new entrant to apply these models to a specific location and time; hence the recommendation to approach experts in the field. **Woody Biomass.** An empirical forest biomass yield model has been developed by Nishizono et al. (2005). This table can be used to determine the unutilized woody biomass volume produced by a timber harvest. Treitz et al. (2012) demonstrates a tool for the estimation of forest inventory variables at the plot and stand levels for specific forest types using a LiDAR point density of 0.5 pulses·m-2. Such a tool could be applied to accurately estimate forest inventory variables and subsequently, biomass yield. Distinct tools can also be used for modelling the availability of, and suggested extraction rates for deadwood (Venier et al. 2015). Huggard & Kremstater (2007) present a synthesis of published technical literature that can be used to parameterize and model deadwood harvesting projects. **Guidance for Reporting Recommendation 1** Mitigation steps for poor yield variability could include identifying high-yielding regions nearby, improving management practices and crop rotations to improve soil fertility and prairie strips to intersperse energy crops with row crops.
Guidance Source	Abt (2018, interview); Busby et al. (2017); Chawla et al. (2016); FAO (2017); Golecha & Gan (2016); Hladik (2017, interview); Huggard & Kremsater (2007); Jager et al. (2010); Jenkins (2017, interview); Jeong et al. (2016); Jiang et al. (2017); Newlands & Townley-Smith (2010); Nishizono et al. (2005); Passmore (2017, interview); Phys-Org (2017); PNNL (2017); SOFAC (2018); Treitz et al. (2012); Venier et al. (2015)

3.1.6 DOUBLE-COUNTING FEEDSTOCK

Rationale	Aggregators, intermediaries or brokers organize and distribute feedstock produced by suppliers. If such sources of supply are used in assessing feedstock availability for BAMs or supply curves, Proponent should be sure not to double count feedstock produced by one supplier and traded/supplied by an intermediary.
Reporting	**Reporting Recommendation 1** 1. Sources of feedstock for brokers, intermediaries or aggregators should be disclosed.

Guidance	**Guidance for Reporting Recommendations 1** In case of brokers and intermediaries, sources of feedstock should be disclosed, otherwise the quantities claimed by brokers/intermediaries could misinform total feedstock availability (Marsollek 2018, interview). Non-circumvention agreements may be required prior to disclosure of sources.
Guidance Source	Marsollek (2018, interview)

3.1.7 FRONT-END VALIDATION OF DATA USED IN FEEDSTOCK AVAILABILITY MODELS

Rationale	Feedstock supply models can be complex. Lack of clarity about model assumptions and baseline data can result in confusion on the part of the capital markets and drive financing costs for biomass projects. The adequacy and credibility of assumptions and baseline data is paramount to credible model outputs.
Reporting	**Reporting Requirements** 1. Data behind feedstock supply models shall be transparent and credible. 2. Samples of data underlying feedstock supply models shall be verified. **Reporting Recommendations** 1. If possible, alternative data sources should be considered to validate primary data used on model.
Guidance	**Guidance for Reporting Requirement 1** Credibility of any model depends on the credibility of data going into the model. Trust in the model can depend on the understanding of the sources of data and their credibility. Any data used in the model therefore shall be referenced, and if possible, the methodology behind data collection shall be clearly articulated. In case of primary data collected specifically for the Proponent, the methodology behind data collection shall be explained. **Woody Biomass.** In the US, the most credible source of secondary data pertaining to biomass available from US forests, including pulpwood, is the Forest Inventory and Analysis (FIA) database published by USDA Forest Service. **Guidance for Reporting Requirement 2** No dataset is a perfect representation of reality. Data collection methods can result in datasets with potentially large errors. This is especially the case of point-source data; meaning, data collected from Proponents. Supplier information should be verified through direct conversations with suppliers or site visits. More general data, such as county-level information, can be verified by cross-referencing with alternative datasets, if available. Whenever possible, data shall be verified by an independent, credible third party. **Guidance for Reporting Recommendation 1** If data are available from more than one source, alternative sources should be considered. Preferably, alternative data sources should be run through the model and results should be compared. A wide discrepancy of results can indicate an unreliability of available datasets, in which case a decision can be made to apply more conservative outputs.
Guidance Source	Dujmovic (2019, feedback); USDA (2014)

3.2 Risk Factor: Historical Issues

3.2.1 HISTORICAL FEEDSTOCK PRICE VARIATIONS AND “RED-LINE” FEEDSTOCK COST

Rationale	If volatility is shown in the historical feedstock price, then the risk of future price fluctuation is elevated. If feedstock prices have historically exceeded the price at which the Proponent would have to cease operations or breach a financial covenant (i.e., the “red-line” feedstock cost), then mitigation measures should be put in place.
Reporting	**Reporting Requirements** Proponent shall: 1. Identify drivers of historical feedstock price variations 2. Assess probability and impact of price drivers occurring in the future and impact on feedstock availability and price 3. Compare their “red-line” feedstock cost with historical maximums and describe mitigation measures, if required.
Guidance	**Guidance for Reporting Requirement 1** The longer the historical horizon of data provided for predictive analysis, the more accurate the results. At minimum, 5 years of historical feedstock price shall be analyzed. Risk is greater where no historical feedstock price data are available. **Guidance for Reporting Requirement 2** It is also possible to develop quantitative estimates of this probability as shown by researchers at INL using the Stochastic Techno-Economic Model (Hansen et al. 2018). Feedstock price variations can fluctuate due to multiple factors. For example, catastrophic weather events can cause spikes in feedstock price, surges in the housing market can depress cost of sawmill chips. Understanding timber supply and demand trends can aid in the understanding of variations in historical feedstock prices (Abt et al. 2000; 2009). Capital-at-Risk (CaR) and Value-at-Risk (VaR) are concepts used in financial risk assessments to evaluate the financial viability of a project (Jorion 2007). Recently, they have begun to be used to assess the financial risks of biomass supply chains. Hansen et al. (Hansen 2018) are investigating the stochastic, financial risk of biomass supply chains using the STEM model. They will be including the VaR and CaR metrics based on the work of Jorion (2007) in the model. These metrics provide quantitative estimates of financial risk at a specified confidence level. **Guidance for Reporting Requirement 3** If the Project cannot withstand historical price highs, they should provide rationale as to why feedstock price is unlikely to reach such highs in the future.
Guidance Source	Abt et al. (2000; 2009); Carollo (2017, interview); Jenkins (2017, interview); Jorion (2007); Hansen et al. (2018); Mills (2017, interview); O’Leary (2017, interview); Santibanez-Aguilar et al. (2016)

3.2.2 LOW HISTORICAL DEMAND FOR FEEDSTOCK IN THE SUPPLY BASIN

Rationale	If Proponent supply basin does not have history of developed, large-scale feedstock procurement, suppliers may not have sufficient expertise in feedstock production to ensure reliable supply, especially in early years. This can be particularity true for forest residues where typically the infrastructure for collection, processing and delivery is immature. Where supply chains are not well-established, risk can be mitigated when Proponent controls a higher degree of feedstock processing. For example, if a Proponent requires clean wood chips and the historical demand in the woodshed is exclusively for pulpwood, then supply chain risk will be decreased by Proponent’s intake of pulpwood and internal log debarking and chipping, rather than requiring inexperienced suppliers to deliver debarked wood chips.

Reporting	**Reporting Requirements** 1. Understanding of historical feedstock production in the supply basin shall be demonstrated, including an assessment of the degree of risk presented by feedstock production history and supply expertise. If necessary, mitigation strategies shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Education-based training and transition programs with the local labor force should be considered in areas where lack of previous supply experience is evident. As the proportion of feedstock removed from the land increases, so does the cost-per-unit to remove the feedstock. In other words, there is a point at which feedstock removal from the landscape becomes cost prohibitive. Understanding this price point is useful in determining the ideal ratio of residue removal. For example, Ralevic et al. (2010) estimate that due to marginal cost of forest residue extraction, 25-59% of potentially available biomass would remain in the forest.
Guidance Source	Huhnke (2017, Comment 1); Mills (2017, interview); Ralevic et al. (2010); Webster (2017, interview)

3.2.3 HISTORY OF PRODUCTION/FEEDSTOCK IS A NEW/SECONDARY CROP OR A BY-PRODUCT

Rationale	If feedstock is a new/secondary crop or a by-product, suppliers may either lack sufficient experience to mitigate risk, or be unable to react to such risk. Secondary crop or by-product producers may be less likely to prioritize production. For new crop types, inexperience in planting, harvest, collection and yield data may pose higher levels of risk. If feedstock is a secondary crop, then production can be subject to variables beyond suppliers' control (e.g., changing primary crop prices).
Reporting	**Reporting Requirements** 1. Proponent shall determine primary product/crop production levels that are necessary to sustain feedstock production. 2. Proponent shall demonstrate understanding of the market drivers for primary product on which by-products or secondary feedstock depends.
Guidance	**Guidance for Reporting Requirement 1** Employ primary crop yield models to determine secondary crop production. The most accurate models involve satellite data analysis (Muth 2017).
Guidance Source	Muth (2017, interview)

3.3 Risk Factor: Non-Weather Based Externalities

3.3.1 DIESEL, OIL AND PRODUCER PRICE INDEX (PPI)

Rationale	Diesel, oil and PPI can impact feedstock cost of harvest and collection over time. Sensitivities to worst case scenarios should be run.
Reporting	**Reporting Requirements** 1. Feedstock price risk relating to diesel/oil cost and PPI fluctuations and its impact on the Proponent shall be evaluated for a 10-year period. *NOTE: Impacts of diesel on transport cost should not be calculated here (see 3.5.3).*

Guidance	**Guidance for Reporting Requirement 1** Historical price fluctuations of feedstock in the supply basin should be modeled with/without diesel/oil prices and PPI to understand the degree to which fluctuations in fuel or labor present long-term supply chain risk. Techno-economic models can be used where feedstock markets have not yet been established, and lack of historical data does not allow for establishment of correlations. Techno-economic models include feedstock logistics and optimization models designed to estimate transportation routes and costs Lamers et al. (2015a, b).
Guidance Source	Curran (2017, interview); Lamers et al. (2015a, b); Passmore (2017, interview)

3.3.2 CURRENCY RISK

Rationale	Where feedstock is purchased in a currency different than that which the plant and markets use to operate, currency exchange rates and volatility can constitute risk exposure. Plants near the US-Canada border which intake feedstock from both countries are exposed to such currency risk.
Reporting	**Reporting Requirements** 1. Proportion of Proponent feedstock which is sourced cross-border shall be identified by quantity and cost. 2. Cross-border suppliers of particular importance shall be identified. 3. The impact of reasonable exchange fluctuations on feedstock cost shall be assessed for at least a 10-year period.
Guidance	
Guidance Source	Solomon (2019, interview)

3.3.3 BORDER RISK

Rationale	Where feedstock is transported cross-border to another country, risk exposure to border closures and crossing delays becomes present. The availability of trucks willing to do cross-border runs is limited which can decrease supply chain flexibility and resilience. Plants near the US-Canada border which intake feedstock from both countries are exposed to these risks.
Reporting	**Reporting Requirements** 1. Proportion of Proponent feedstock which is sourced cross-border shall be identified by quantity and cost. 2. Cross-border suppliers of particular importance shall be identified. 3. The impact of border delays/shutdown on feedstock cost shall be assessed for at least a 10-year period.
Guidance	
Guidance Source	Solomon (2019, interview)

3.3.4 TEMPORARY EXTERNALITY-DRIVEN MARKETS FOR FEEDSTOCK

Rationale	Alternative, non-traditional, externality-driven competitors for feedstock can drive feedstock demand (and cost) in unusual circumstances. For example, a Proponent using corn stover as a feedstock would not typically compete with the higher-end animal feed market. However, in times of significant hay shortage (e.g., during drought), farmers may use corn stover as hay replacement, driving the price of stover feedstock and decreasing its availability for bio-projects (Bergtold 2018).
Reporting	**Reporting Requirements** 1. Any alternative, non-traditional and externality-driven markets for feedstock shall be identified, and the likelihood and impact of these markets upon the Proponent shall be assessed.

Guidance	**Guidance for Reporting Requirements 1** **Agricultural Residues.** In general, demand for feedstock from high-value markets is small. For example, research in Manitoba shows that estimated maximum needs for cattle feed/bedding and livestock bedding are ~1% of available crop residues (Gunn 2019). Despite this (in most circumstances) negligent impact of high-value markets on agricultural residue availability, the estimated demand should be demonstrated to ease any elevated perception of risk posed by these markets.
Guidance Source	Bergtold (2018, interview); Gunn (2019, feedback)

3.4 Risk Factor: Risks Related to Feedstock Production, Harvest and Collection

3.4.1 HARVEST AND COLLECTION PRACTICES AND SCHEDULES

Rationale	Differences in harvest timing and practices used can create risk to both the quantity and quality of feedstock. For example, feedstock harvested by different suppliers in different windows can undergo varying levels of exposure to sun, wind and moisture, leading to variations in delivered feedstock quality. For example, agricultural feedstocks and energy crops have optimal harvesting windows to ensure minimal moisture content. In certain regions these harvesting windows may coincide with heightened weather risk such as frost or rain. For forestry biomass, unsightly clear cuts and slash piles (even on plantation forests and especially when located near communities) can provoke unwanted public backlash even when suitable and sustainable replanting regimes are followed.
Reporting	**Reporting Requirements** 1. Understanding of feedstock harvest practices and schedules shall be demonstrated. 2. Understanding of weather risk and its impact on feedstock quantity and quality in relation to harvesting schedules shall be demonstrated. 3. Understanding of any potential public backlash to harvest practices shall be demonstrated. **Reporting Recommendations** 1. Typical harvesting schedule and Proponent's planned delivery schedule for feedstock should be prepared.
Guidance	**Guidance for reporting requirement 1** Feedstock harvest schedules can be acquired directly from suppliers. Misalignment of suppliers' harvest schedules with Proponent's required feedstock quantities can create supply shortages. **Guidance for reporting requirement 2** Preferably, harvesting should be scheduled during periods of low weather risk. Harvesting, collection and delivery schedules should be based on feedstock's propensity to degrade (Huhnke 2017).
Guidance Source	Ebadian et al. (2011); Huhnke (2017, interview); Nguyen (2018, comment); Spikes (2017, interview)

3.4.2 HARVESTING AND COLLECTION EQUIPMENT

Rationale	Different types of harvesting and collection equipment used by suppliers can have a significant impact on the quality and availability of feedstock. Use of different types and combinations of harvesting, collection and processing equipment among suppliers can lead to non-homogeneous feedstock. Equipment that is not designed specifically for biomass cultivation, harvesting and collection, can increase feedstock quality risks. Relevant equipment should be specified for the sake of product consistency and risk reduction.
Reporting	**Reporting Requirements** 1. Understanding of equipment requirements to produce high-quality feedstock shall be demonstrated, including all equipment typically used for harvesting, collection and processing. 2. Understanding of equipment variety in the supply chain, and its impact on feedstock quality consistency shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Proponent shall develop a harvesting, collection and processing equipment specification sheet for use by suppliers. Data can be acquired from equipment manufacturers. Researchers at INL, ORNL, and Antares (FOA Project) maintain a list of recommended harvest equipment, their yields and collection efficiencies, applicable to corn stover and energy crop harvests (Nair et al. 2018a, b). **Guidance for Reporting Requirement 2** Site visits to audit equipment are preferable over verbal information provided by suppliers. A wide variety of equipment in the supply chain can make it difficult for suppliers to quickly acquire spare parts. For example, Webster (2017) suggests that variations in equipment leading to lower access to spare parts can affect the supply chain's uptime by 30%. This is because distributors of spare parts keep inventory in locations with higher demand. Regions where a large number of feedstock suppliers own the same equipment will be served better by spare-part distributors.
Guidance Source	Nair et al. (2018a, b); Smith (2017, interview); Spikes (2017, interview); Webster (2017, interview)

3.4.3 VARIATION IN DENSIFICATION METHODS AMONG DIFFERENT SUPPLIERS

Rationale	The shape and density of the unit in which feedstock is supplied can impact feedstock cost and quality. Standard feedstock densification modes for biomass consist of round or square bales, pellets, cubes, chips, or grindings. The size of wood fibre processed in a grinder is less homogenous than if a chipper is used. Bales of different densities can absorb moisture at different rates. In certain cases, round bales have been viewed as problematic due to their uneven moisture content distribution (Huhnke 2018).
Reporting	**Reporting Requirements** 1. Understanding of the impacts of different modes of feedstock densification shall be demonstrated
Guidance	**Guidance for Reporting Requirement 1** A third-party company specializing in feedstock harvesting and use of standard densification equipment can function to ensure consistency and decrease risk if a variety of feedstock modes are present in the supply basin. *NOTE: Even if a specific mode of feedstock densification is identified as preferable, suppliers may not have an ability to densify feedstock in such a way. For example, farmers may not have an ability to produce square bales if current equipment is designed for round.*
Guidance Source	Huhnke (2018, Comment 1); Nguyen (2018, comment); Webster (2017, interview)

3.4.4 AVAILABILITY OF LABOUR FOR FEEDSTOCK PRODUCTION

Rationale	Skilled labor shortages can be difficult to remedy in the short-term. Availability of suitable labor in an area can impact the ability to procure sufficient feedstock quantities on required schedules. Labour risks are higher for greenfield facilities where supply chains are not yet active; or for Proponent's for whom large feedstock requirements, or development of new (or expanded) supply chains, demand significant additions to the local labor force.
Reporting	**Reporting Requirements** 1. Understanding of labor requirements necessary to produce and deliver feedstock shall be demonstrated, including: • Number of trained operators of field equipment • Number of harvesters/loggers • Experience of existing labor force • Necessary laborer certifications.
Guidance	**Guidance for Reporting Requirement 1** The Proponent should have an understanding of the number of contractors within a 75 miles radius, as well as contractors' total harvesting capacity.
Guidance Source	Ebadian et al. (2011)

3.5 Risk Factor: Transportation

3.5.1 FEEDSTOCK TRANSPORTATION COSTS

Rationale	Transportation can be one of the most significant cost components of biomass supply chains. The average transport cost and percentage of total feedstock cost attributable to transport should be known.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Average transportation cost per-unit of delivered material 2. The percentage of total (current and projected) feedstock cost attributable to transport 3. Feedstock cost in relation to transportation cost drivers via a sensitivity analysis 4. Forecasted transportation cost. **Reporting Recommendations** 1. Mitigation plan for escalating transportation costs should be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Understanding of feedstock suppliers' locations, quantity of feedstock sourced at each location, and local infrastructure is necessary for evaluating feedstock transportation costs.
Guidance Source	Curran (2017, interview); Gan & Smith (2011); Roni et al. (2014a, b)

3.5.2 TRANSPORTATION DISTANCES

Rationale	Transport distances of 50-75 miles for biomass feedstocks are typical but larger distances can be common. Where average transport distance from suppliers to Proponent is high, the supply chain is subject to greater sensitivities to risks, such as increases in diesel cost, weather impacts, mechanical breakdown, and by the demand for scarce feedstock from competitors closer to the source. Understanding average transport distance can help flag higher-risk suppliers where transport distance materially exceeds the average.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Average transport distance per delivered unit of material 2. The transport distance from Proponent to all suppliers. **Reporting Recommendations** 1. Optimal transport distance should be modelled.
Guidance	**Guidance for Reporting Requirement 1** Traditionally, the biomass industry has defined the supply basin as an area within a 50-mile drive. This definition differs between various feedstock types. Generally, agricultural residue and energy crop supply basins are smaller than woody biomass woodsheds. **Guidance for Reporting Recommendation 1** Optimal transportation distance is dependent on locations of competitors with respect to suppliers. Since suppliers prefer to deliver to buyers located closer, the optimal transportation distance decreases with higher density of biomass consumers. Transportation optimization models can be used to determine the most optimal mix of suppliers from a transportation cost perspective. An example of feedstock transportation optimization model for a biomass project can be found in Roni et al. (2014a, b). If average distance is high Proponent may explore possibility of diversifying feedstock type to enable sourcing from closer proximity.
Guidance Source	Roni et al. (2014b); Dujmovic (2019, feedback)

3.5.3 DIESEL

Rationale	Changes in diesel cost impact transport cost over time. Sensitivities to worst case scenarios should be run. If transport cost is not indexed for diesel or risk of diesel price increase shifts to suppliers, supplier margins can be stressed, and supply chain reliability can suffer as a consequence.
Reporting	**Reporting Requirements** 1. The impact of realistic variations in diesel cost shall be evaluated for a 10-year period. 2. Long-term supplier contracts should contain an index accurately reflecting the local price of diesel.
Guidance	**Guidance for Reporting Requirement 2** Diesel price adjustments should be made quarterly or bi-annually.
Guidance Source	Solomon (2018, interview); US Diesel Index Sample; Canadian Diesel Index Sample; Dujmovic (2019, feedback); Gunn (2019, feedback)

3.5.4 TRANSPORT OF FEEDSTOCK REQUIRES SPECIALIZED EQUIPMENT

Rationale	Requirements for specialized transport equipment (e.g., walking-floor trailers) can increase supply chain risk. Where there is low availability in required transportation equipment, equipment owners have increased leverage over transportation prices and supply chain resiliency can be lower.
Reporting	**Reporting Requirements** 1. Understanding of the Project's dependence on specialized transportation equipment and its availability in the supply chain shall be demonstrated. 2. Where the redundancy of required transportation equipment is low, a transportation equipment shortage mitigation plan shall be demonstrated that includes: • Purchase of own transportation equipment • Adjustment of receiving infrastructure to lower transportation equipment requirements.
Guidance	
Guidance Source	

3.5.5 DELIVERY ROUTES THROUGH LOCAL COMMUNITIES

Rationale	Transportation of biomass can become a nuisance to local communities, especially if a large number of trucks pass through residential and school areas. Local communities often have power to force regulations regarding truck transport, impeding a Proponent's ability to transport feedstock. This risk is greater in greenfield projects than operational ones.
Reporting	**Reporting Requirements** 1. Understanding of feedstock transportation routes in relation to current and planned residential developments shall be demonstrated, particularly in relation to downtown, residential or school areas. 2. Assessment of feedstock transportation nuisance to local communities and an associated risk of community backlash shall be made. 3. Where the risk of community backlash is significant, a mitigation plan shall be demonstrated, including alternative delivery routes. Overweight permits and increased feedstock load density can function to reduce number of deliveries.
Guidance	
Guidance Source	Daly & Halbleib (2017, interview); Tan (2018, interview); Dujmovic (2019, feedback)

3.5.6 TRANSPORTATION REGULATIONS AND LOAD WEIGHT LIMITS

Rationale	In many regions, transportation is regulated based on seasonal road conditions. These regulations (e.g., "frost laws") often take the form of weight restrictions or limits on the number of trucks allowed on roads. Such regulations can impede the project's ability to source sufficient feedstock or increase the cost of doing so at certain times of the year.
Reporting	**Reporting Requirements** 1. Understanding of relevant feedstock transportation regulations, especially load weight limits and number of trucks allowed on roads, shall be demonstrated, including those involving: • Seasonality (e.g., "frost laws") • Jurisdictions • Proposed changes to regulations. 2. Where feedstock transportation restrictions pose a significant risk to the Proponent, a mitigation plan shall be demonstrated, including: • The potential to acquire regulatory exemption • Alternative delivery methods (e.g., use of smaller trucks) • Increasing biomass inventory piles in advance of expected seasonal restrictions.

Guidance	**Guidance for Reporting Requirement 1** Provinces and states have increased trucking load restrictions during spring thaws, with variations based on region, type of road, specific dates and duration. For example, Ontario roads are divided into four schedules by the Highway Traffic Act (1990). More restrictive weight limits can increase the number of deliveries required to acquire feedstock, resulting in feedstock cost variation. Regulations can change jurisdictionally on municipal and provincial/state levels. Route planning can be conducted according to these jurisdictional differences. **Guidance for Reporting Requirement 2** Certain municipalities, such as small towns seeking economic development, can sometimes be incented to provide regulatory exemptions to feedstock transport.
Guidance Source	Tudman & Hvisdas (2018, interview)

3.5.7 ROAD INFRASTRUCTURE

Rationale	Feedstock cost and availability can be a function of road infrastructure, in particular the accessibility the infrastructure provides to feedstock. Issues with road networks will translate directly to risks to feedstock supply.
Reporting	**Reporting Requirements** 1. Understanding of transport supply routes and their effect on feedstock cost and availability shall be demonstrated, including understanding of weather patterns and their effect on road conditions.
Guidance	**Guidance for Reporting Requirement 1** Paved roads are preferable to unpaved and resource roads, especially in wet seasons. Some roads can become impassable during heavy rainfall and snowfall conditions (Huhnke 2017).
Guidance Source	Gan & Smith (2011); Huhnke (2017, interview); O'Leary (2017, interview)

3.5.8 BACKHAULS

Rationale	In some cases, Proponent's transportation economics can be dependent on other non-related industries such as using backhauls to make feedstock economically viable. If viability of transport depends on backhauls, supply chain risk is elevated (Davis 2018). If the backhaul is lost, transport costs can spike or supplies may disappear altogether.
Reporting	**Reporting Requirements** 1. Understanding of the degree to which feedstock transportation economics depend on backhauling shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** "Backhauling" refers to an arrangement where the hauler maximizes transportation efficiencies by filling the truck at or near the point of discharge, preventing an empty return. Since the hauler earns margin both ways, the transport cost on the "head-haul" is reduced.
Guidance Source	Davis (2018, interview)

3.5.9 TRANSPORTATION REDUNDANCY

Rationale	Transport equipment redundancy is important for dealing with seasonally variable feedstock supplies as well as the risk of equipment breakdowns.
Reporting	**Reporting Requirements** 1. Understanding of transportation redundancy in the supply basin shall be demonstrated in relation to Proponent's feedstock requirements and to feedstock production. **Reporting Recommendations** 1. Where transportation equipment redundancy is low, a mitigation plan should be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Delivery of feedstock after harvesting/processing is often time sensitive, especially when dealing with seasonal feedstocks. Transportation systems should have the capacity to transport increased volumes of seasonally variable feedstock. Benchmarking should involve an analysis of worst-case scenarios. If risks are high, Proponent may specify use of rental equipment from businesses that have a demonstrably adequate supply of similar equipment to assure redundancy. Particularly high risks can be mitigated by Proponent purchasing transport equipment, or by supporting the purchase thereof by third-party transport companies.
Guidance Source	Cook (2018, interview); (Marsollek 2018, interview)

3.6 Risk Factor: Supply Chain Resiliency

3.6.1 NUMBER, SIZE MIX AND LOCATIONS OF SUPPLIERS

Rationale	In general, a supply portfolio involving multiple suppliers of various sizes (and from multiple regions) is important for ensuring steady and uninterrupted feedstock supply with minimal price fluctuations. If a small number of large suppliers provides a high proportion of total feedstock, a disruption or supplier breach will have greater impact on the supply chain. In such cases the risk of disruption is lower but the impact of those disruptions is higher. Conversely, a large number of small suppliers are less likely to have the capacity to withstand internal disruptions and thus may be more likely to breach. Here, risk of disruption is higher but their likely impact is lower. The number of suppliers as well as the ratio of small to large suppliers should be optimized. There is no pre-determined number or optimal ratio of suppliers, although having too many or too few can both pose higher degrees of risk.
Reporting	**Reporting Recommendations** Proponent shall demonstrate understanding of: 1. Minimum number of feedstock suppliers required to minimize feedstock supply risk 2. Maximum proportion of Proponent's total feedstock requirement that one supplier controls 3. Optimal number of small and large suppliers in the supply chain 4. Impact of geographic locations of suppliers (i.e., supplier density) on supply chain resilience.
Guidance	**Guidance for Reporting Recommendation 1** Current best approaches to modelling biomass supply chains are based on agent-based models (Hartley 2017). Examples of such models can be found in De Meyer et al. (2014); Cambero & Sowlati (2014); An & Searcy (2012); Dunnett et al. (2007); and Gharder et al. (2016). Scenario-based models can be used to test various supply chain configurations and determine the lowest risk configuration.

	Supply basins should consist of at least 15-20 suppliers to adequately de-risk the supply chain (Rainey 2017). **Guidance for Reporting Recommendation 2** In general, risks can be elevated if more than 1/3 of the total supply is provided by a single supplier. **Guidance for Reporting Recommendation 3** **Woody Biomass.** Opinions vary with regards to the optimal mix of small to large suppliers. For example, O'Leary (2017) suggests that 1/5 of suppliers should be relatively large, while others say the ratio of small to large suppliers should be closer to 1:1 **Guidance for Reporting Recommendation 4** Sustainable and efficient operation of a biomass supply chain is highly dependent on the underlying spatial and temporal components, even for reasonably small supply basins.
Guidance Source	An & Searcy (2012); Cambero & Sowlati (2014); De Meyer et al. (2014); Dunnett et al. (2007); Freppaz et al. (2004); Gan & Smith (2011); Gebreslassie et al. (2012); Gharderi et al. (2016); Golecha & Gan (2016); Hartley (2017, interview); Howes (2018, interview); Jenkins (2017, interview); Nguyen (2017, interview); O'Leary (2017, interview); Passmore (2017, interview); Rainey (2017, interview); Smith (2017, interview); Webster (2017, interview); Jenkins (2017, interview)

3.6.2 SUPPLIERS SUBJECT TO SAME EXTERNAL RISK FACTORS

Rationale	When a single risk event can impact the feedstock production ability of all (or most) suppliers, then feedstock risk is higher and supply chain resiliency is lower. Resilience is maximized when biomass supply chains exhibit diversity in spatial location (i.e., geography), production practices and other elements of supply chain structure such that the impact of single high-risk events have varying impacts on suppliers.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. The set of common risks that impact over 75% of the supply chain by feedstock quantity. 2. Factors that mitigate the set of common risks, including: • Spatial location (i.e., degree to which suppliers are clustered together) • Soil composition (i.e., drainage profile) • Land ownership • Supply chain structure • Regulatory zones 3. Proportion of suppliers and supply that are subject to the same external risk factors 4. Maintenance of suitably sized inventory piles and pre-arrangements for redundant feedstock with non-local suppliers where a high proportion of supply is subject to the same external risk factors.
Guidance	**Guidance for Reporting Requirement 2** The more geographically compressed suppliers are in the supply chain, the more likely they are to be subject to a single risk. For example, suppliers who are clustered together in a particular area could all be subject to soil condition risks (e.g., sandy versus clay-based soils) that may affect soil drainage and thus limit the ability for forestry operations to access sites after severe rains due to flooding. Having suppliers operating in areas with both types of soils can mitigate the risk of supply disruptions due to excessive rainfall. It is acknowledged that mitigation can be difficult for common occurrences that can lower the resiliency of the entire supply chain. Examples of these include: • Sawmills dependent on the housing market • Stover producers dependent on the markets for corn • Energy crop producers dependent on rainfall. **Guidance for Reporting Requirement 4**

	Feedstock inventory, whether at the facility yard or in satellite storage depots, acts as a buffer to supply chain disruptions.
Guidance Source	

3.7 Risk Factor: Climate and Natural Risks

3.7.1 SEASONAL WEATHER IMPACTS ON FEEDSTOCK SUPPLY

Rationale	Seasonal weather impacts are defined as those deriving from natural weather variations (i.e., spring thaws, rainy seasons or dry seasons – as opposed to from singular weather events like fires, droughts or hurricanes). Seasonal weather changes can be a significant risk factor affecting feedstock availability, quality and price. Given the major influence that weather has on multiple aspects of growing, harvesting and transporting biomass, it is difficult to predict the availability of biomass at a specific location at different points in the future with a high degree of certainty. However, it is still possible, using past data and statistical models, to generate reasonable upper/lower bound estimates of biomass production in any given year in a wider supply basin. Such estimates are important in assessing feedstock risk and enable accurate assessment of the efficacy of Proponent's mitigation methods.
Reporting	**Reporting Requirements** 1. Understanding of weather patterns in the supply basin and their potential impacts to feedstock production shall be demonstrated. 2. Where high risk of feedstock shortage due to weather exists, a mitigation plan shall be demonstrated **Reporting Recommendations** 1. Forecasting and propagation models should be applied in analyses of weather impacts.
Guidance	**Guidance for Reporting Requirement 1** Historical data is needed for credible forecasting. 10 years of weather data should be obtained if possible. Worst-case scenarios should be simulated to determine the risk of feedstock shortage. Understand how, and to what degree, seasonal weather has impacted the feedstock supply chain in the past. Historical modelling of seasonality, and weather impacts on feedstock availability, quality and price can be instructive. **Guidance for Reporting Requirement 2** Mitigation measures include inventory planning on a multi-year scale. Part of biomass collected in an excess-production year may be used as inventory to meet a lower-production event the following year if storage issues (e.g., decomposition) can be addressed. As prices drop with oversupply and rise with undersupply, such strategies can help mitigate impacts of inter-year variabilities. Insurance against undesirable impacts from weather change are sometimes available to ensure long-term sustainability of an operation. Proponent may investigate whether such products are available to it or to suppliers.
Guidance Source	An & Searcy (2012); Crummett (2017, interview); Curran (2017, interview); Ebadian et al. (2011); Hladik (2017, interview); Nguyen (2017, interview); Rob (2017, interview); D. Smith (2019, feedback)

3.7.2 LONG-TERM WEATHER AND CLIMATE TRENDS

Rationale	In certain regions, climatic trends and significant potential changes to future weather patterns can create feedstock risk.
Reporting	**Reporting Requirements**

	1. Assessment of impact of future weather patterns or climactic changes on feedstock availability and price shall be demonstrated. 2. Where risk of changing weather patterns and/or climatic trends and their detrimental impact to feedstock availability is significant, a mitigation plan shall be demonstrated.
Guidance	**Guidance for Reporting Requirements 1** In Canada, Climate Change Impacts and Adaptation Division (CCIAD) leads the development of collaborative, national and sectoral science assessments that present the latest knowledge on climate change impacts and adaptation. These assessments are scientific reports that assess, critically analyze and synthesize the growing knowledge base on the issue. Working with subject matter experts in government, universities and non-government organizations, CCIAD produces science assessments that are current, relevant and accessible sources of information, to help inform planning of policies, program and action. The following publications are available from Climate Change Impacts and Adaptation Division (CCIAD): *From Impacts to Adaptation: Canada in a Changing Climate (2008)* assesses risks and opportunities presented by climate change, and actions being taken to address them, from a regional perspective. *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*. An update to the 2008 report. *From Impacts to Adaptation: Canada in a Changing Climate*. Assesses literature published since 2007 on climate change impacts, adaptation and vulnerability in Canada. It includes chapters on natural resources, food production, industry, biodiversity and protected areas, human health, and water and transportation infrastructure. *Canada's Marine Coasts in a Changing Climate*. Assesses climate change sensitivity, risks and adaptation along Canada's marine coasts. The report includes overviews of regional climate change impacts, risks and opportunities along Canada's three marine coasts, case studies demonstrating action, and discussion of adaptation approaches.
Guidance Source	Daly & Halbleib (2017, interview);

3.7.3 FOREST/CROP FIRE

Rationale	Forest/crop fires, especially when occurring at large-scale, destroy feedstock and create shortages. Fire-prone conditions are predicted to increase across the country. This could potentially result in a doubling of the amount of area burned by the end of this century compared with amounts burned in recent decades. Boreal forests, which have been historically greatly influenced by fire, will likely be especially affected by this change. Other climate change impacts that could add damaged or dead-wood to the forest fuel load (e.g., as a result of insect outbreaks, ice storms or high winds) may increase the risk of fire activity. New research is aimed at refining these climate change estimates of fire activity, and at investigating adaptation strategies and options to deal with future fire occurrence. There is growing consensus that as wildfire activity increases, fire agency suppression efforts will be increasingly strained. However, analyses of fire history suggest that it is the effect of climate variability on precipitation regimes that is the primary reason for the decreasing fire activity in the southern region of Canada.
Reporting	**Reporting Requirements** 1. Understanding of forest/crop fire risk and its impact to feedstock supply shall be demonstrated. 2. Mitigation plan to minimize forest/crop fire risk shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** An analysis of historical forest/crop fire occurrence and the likelihood of future fire occurrence should be conducted.

	Rabin et al. (2018) have developed a model for predicting fire patterns in both non-agriculture land, and cropland. This model can be used for estimating the future prevalence of cropland fires across North America. Ager et al. (2018) describe statistical modelling techniques for forest fire occurrences. The model accounts for both natural and human ignition sources, as well as feedback systems and management activities. The findings of the model are also compared to other similar simulations, and can be applied for many forest fire modelling applications. A general framework to assess forest wildfire risk using multiple data sources and modelling techniques can be found in Saglam et al. (2008) and Scott et al. (2013). New approaches using remote sensing (i.e., satellite and drone imagery) and digital technology can be applied to determine the risk of fire. Examples of application of high-resolution remotely-sensed imagery to assess the risk of agricultural field fire can be found in Verbesselt et al. (2006); Nielsen & Rasmussen (2001); Sannier et al. (2010); Mbow et al. (2004); and Smith et al. (2005). Vegetation water content (VWC) is a major factor in remotely-sensed imagery analyses used to evaluate fire risk. VWC is defined as water volume per leaf, water volume per ground area (or equivalent water thickness), or water mass per mass of vegetation dry matter. Application of this analysis can be found in Agee et al. (2002); Maki et al. (2004); and Vesserbelt et al. (2006). Quantity of biomass in the forest/field is a critical factor in assessing risk of fire, and can be evaluated through remotely-sensed imagery. Application of this analysis can be found in Mbow et al. (2004); Van Wilgen et al. (2000); and Vesserbelt et al. (2006). **Guidance for Reporting Requirement 2** A general framework for developing a mitigation plan for forest wildfire risk can be found in Scott et al. (2013).
Guidance Source	Agee et al. (2002); Ager et al. (2018); Bessa & Block (2017); Chuvieco et al. (2004); Leblon et al. (2001); McGill & Darr (2014); Maki et al. (2004); Maselli et al. (2003); Mbow et al. (2004); Nielsen & Rasmussen (2001); Rabin et al. (2018); Saglam et al. (2008); Sannier et al. (2010); Scott et al. (2013); Smith et al. (2005); Van Wilgen et al. (2000); Webb (2016)

3.7.4 RISK OF INFESTATION

Rationale	Risk of future infestation, including its estimated consequences on feedstock supply, should be calculated into the overall risk profile. Since forest insect populations are influenced by environmental conditions, future changes in climate can be expected to significantly alter the outbreak dynamics of certain forest insect species. In some cases, larger and more frequent insect outbreaks may occur, but in other cases recurring outbreaks may be disrupted or diminished. As climate continues to change, we can expect more situations, particularly at the margins of tree ranges, where sub-optimal conditions for tree growth and reduced tree vigor can lead to outbreaks of forest insects.
Reporting	**Reporting Requirements** 1. Historical occurrences of infestation of Proponent feedstock shall be understood along with vectors through which infestation have historically occurred. 2. Future risk and impact of infestation shall be assessed.
Guidance	**Guidance for Reporting Requirement 1** Infestation of timber forests or agricultural croplands is dependent on multiple factors, including: • Biology of pest species

	• Ecology of the forest or agricultural sites • Suitability of the trees or crops of interest as a sustainable habitat for the pest, • The ability of the pest species to colonize and grow as an invasive species in competition with pre-existing species. Various management practices and their effectiveness in suppressing and preventing the spread of infestation once detected have been developed. These practices include thinning, fire treatments, salvage removal and cut-and-leave (Fettig et al. 2007). **Guidance for Reporting Requirement 2** Models should be used to identify known pests that have infested and adversely impacted the tree-population or tree-growth in a forest of interest or on agricultural yields in a given region. Models have been presented to estimate the risks of non-native invasive pest-species established after being transported via cargo, as well as invading via encroachment on a subcontinental scale (Bartell & Nair (2004); Stanaway et al, (2001); Yemshanov et al. (2009a). **Woody biomass.** Bark beetles, a large and diverse group of insects consisting of about 550 species (including southern pine beetle (SPB)) have been identified in North America as the most important mortality agent in coniferous forest, affecting forests on the west and each coasts (Fettig et al. 2007). Effective management practices specific to SPB have been developed and are described by Clarke & Nowak (2009).
Guidance Source	Bartell & Nair (2004); Bentz et al. (1993); Bone et al. (2013); Cerroni & Shaw (2012); Clarke & Nowak (2009); Cole & McGregor (1983); Curran (2017, interview); Dymond et al. (2006); Fettig et al. (2007); Gan (2004); Gansner et al. (1984); Koch et al. (2009); Krupinsky et al. (2002); Lippitt et al. (2008); Overbeck & Schmidt (2012); Reed & Errico (1987); Robertson et al. (2008); Stadelman et al. (2014); Stanaway et al. (2001); Walter & Pratt (2013); Yemshanov et al. (2010;, 2009a, b)

3.7.5 RISK OF HAIL

Rationale	Hail has negligible impact of forestry biomass but is one of the principal destroyers of agricultural crops in North America. There is much uncertainty about the effects of anthropogenic climate change on the frequency and severity of extreme weather events like hailstorms and their subsequent economic losses. Some studies indicate a strong positive relationship between hailstorm activity and hailstorm damage, as predicted by minimum temperatures using simple correlations. This relationship suggests that hailstorm damage may increase in the future if global warming leads to further temperature increase.
Reporting	**Reporting Requirements** 1. Understanding of hail risk and its potential impact on feedstock supply shall be demonstrated, including likelihood of crop failure due to hail. 2. Where risk of hail is significant, a mitigation plan shall be demonstrated.
Guidance Source	**Guidance for Reporting Requirement 1** Hail forecast can be acquired from the National Weather Service. **Guidance for Reporting Requirement 2** Where there is high risk of hail and its negative impact to feedstock supply, the feedstock procurement plan should account for this risk and inventory should be planned accordingly. Low temperature and/or crop failure insurance should also be purchased, if possible, in such situations.
Guidance Source	Daly & Halbleib (2017, interview); Botzen, W.J. Wouter & Bouwer, Laurens & van den Bergh, Jeroen. (2010)

3.7.6 RISK OF FLOOD

Rationale	Floods can cause catastrophic disruption and delay in feedstock supply. Where there is high risk of flood and thus negative impact to feedstock supply, the feedstock procurement plan should account for this risk, and inventory should be calculated accordingly.
Reporting	**Reporting Requirements** 1. Understanding of the flood risk and its potential impact on feedstock supply shall be demonstrated, including locations of flood plains in relation to the Proponent. 2. Where risk of flood is significant, a flood mitigation plan shall be demonstrated. **Reporting Recommendations** 1. Where Proponent feedstock relies on levees to mitigate flood risk, the levee infrastructure should be assessed. 2. Where risk of flood is significant, Proponent should purchase flood insurance if possible.
Guidance	**Guidance for Reporting Recommendations 2** Flood insurance for biomass is not a common instrument and coverage may be problematic if suppliers are intermediaries. Some weather policies may cover flood.
Guidance Source	Hladik (2017, interview); Passmore (2017, interview)

3.7.7 RISK OF DROUGHT

Rationale	Droughts can cause significant disruptions to feedstock supplies across entire regions for extended periods of time, especially in case of agricultural residues and energy crops. Many Western States are experiencing more frequent and severe droughts, and scientists expect drought to affect new areas across the country going forward. Tree species are adapted to specific moisture conditions. Having less water available through drought has a range of negative impacts on the health of forest ecosystems. Direct impacts include reduced growth, increased tree mortality and failure to regenerate. Indirect impacts include reduced ability to defend against insects and disease, and increased fire risk. These impacts can affect the availability of wood fibre for a Proponent.
Reporting	**Reporting Requirements** 1. Understanding of drought risk and its potential impact on feedstock supply shall be demonstrated, including likelihood of future drought in the supply basin. 2. Where risk of drought is significant, a drought mitigation plan shall be demonstrated. **Reporting Recommendations** 1. Where risk of drought is significant, drought insurance should be purchased.
Guidance	**Guidance for Reporting Requirement 1** Vegetation water content (VWC), available from hyper-temporal satellite data, can be used to assess vegetation water stress and drought conditions (Jackson et al. (2004); Pyne et al. (1996); Tucker (1979)), and to assess fire risks; the probability of which increases during droughts under high vegetative cover. **Guidance for Reporting Requirement 2** Where there is high risk of drought and its negative impact to feedstock supply, the feedstock procurement plan should account for this risk and inventory should be planned accordingly.
Guidance Source	Jackson et al. (2004); Pyne et al. (1996); Tucker (1979)

3.7.8 RISK OF HURRICANES, TORNADOES AND STRONG WINDS

Rationale	Hurricanes, tornadoes and strong winds can destroy timber stands, crops and feedstock piles. They can also delay forestry and agricultural operations. Hurricanes and tornadoes can indirectly cause temporary shortages of available transportation as available trucking moves to handle higher value disaster related contracts. For example, Katrina cleanup limited availability of live-bottom trailers in the North and south-east of the US for several months as truckers shifted operations to handle more lucrative government contracts. Although scientists are uncertain whether climate change will lead to an increase in the number of hurricanes, warmer ocean temperatures and higher sea levels are expected to intensify their impacts. Recent analyses conclude that the strongest hurricanes occurring in some regions including the North Atlantic have increased in intensity over the past two to three decades.
Reporting	**Reporting Requirements** 1. Understanding of the hurricane, tornado and strong winds risk and its potential impact on feedstock supply shall be demonstrated, including likelihood of future hurricane, tornado and strong winds in the supply basin. 2. Where risk of hurricane, tornado, or strong winds is significant, a mitigation plan shall be demonstrated. **Reporting Recommendations** 1. Where risk of hurricane, tornado, or strong wind is significant, hurricane insurance should be purchased.

Guidance	**Guidance for Reporting Requirement 1** For the continental US in the Atlantic Basin, models project a 45-87% increase in frequency of Category 4 and 5 hurricanes, despite a possible decrease in the frequency of storms overall. **Guidance for Reporting Requirement 2** Where there is high risk of hurricane, tornado or strong winds, the feedstock procurement plan should account for this risk and inventory should be planned accordingly.
Guidance Source	

3.7.9 LOW TEMPERATURES

Rationale	Low temperatures can cause crop failure, leading to shortages of biomass. Additionally, low temperatures can have adverse impacts on the operations of feedstock processing equipment in northern regions.
Reporting	**Reporting Requirements** 1. Understanding of low temperature risk and its potential impact on feedstock supply shall be demonstrated, including: • Likelihood of future low temperatures • Likelihood of crop failure due to low temperatures • Likelihood of equipment failure due to low temperatures. 2. Where risk of low temperatures is significant, a mitigation plan shall be demonstrated. **Reporting Recommendations** 1. Where risk of low temperatures is significant, low temperature and/or crop failure insurance should be purchased.
Guidance	**Guidance for Reporting Requirement 1** The exact applicable definition of "low temperature" depends on the type of feedstock in question. For example, certain agricultural crops fail in temperatures below zero. Low temperature forecast can be acquired from the National Weather Service. Equipment suppliers should provide information about likelihood of equipment failure due to low temperatures. **Guidance for Reporting Requirement 2** Where there is high risk of low temperatures, the feedstock procurement plan should account for this risk and inventory should be planned accordingly.
Guidance Source	Rainey (2017, interview)

3.8 Risk Factor: Political and Social

3.8.1 GOVERNMENT SUBSIDIES FOR FEEDSTOCK PRODUCTION OR UTILIZATION

Rationale	Feedstock that is directly subsidized though government programs can pose greater long-term risk than feedstock that is not. Subsidies may be subject to amendment or repeal, sometimes with minimal notice. *NOTE: This risk indicator refers to direct feedstock subsides only; it does not apply to government subsidies that pertain indirectly to the operations of the Proponent such as Loan Guarantees or to the markets for products produced by the Proponent.*
Reporting	**Reporting Requirements** 1. Proponent shall indicate any government subsidies that directly relate to feedstock.

	2. Proponent shall estimate the likelihood and impact of removal of such subsidies on feedstock supply. **Reporting Recommendations** 1. In case of existing feedstock subsidies, an alternative to the subsidized feedstock should exist.
Guidance	**Guidance for Reporting Requirement 2** Understanding the likelihood of subsidy cancellation is important to determine feedstock price risks. The social and political environments in which relevant subsidies have come into effect should be understood in order to better predict the likelihood of their alteration or removal. The Biomass Crop Assistance Program (BCAP) in the US is an example of a subsidy program relating directly to feedstock, and for which the long-term continued existence is by no means assured. BCAP subsidizes feedstock supply through provision of matching payments for the collection, harvest, storage and transportation of feedstock (USDA 2018). The sensitivity of feedstock cost or availability to removal of subsidies shall be modeled. The resulting model shall be run against the Proponent's financial model to determine whether the subsidy removal would cause an increase beyond the "red-line" feedstock cost.
Guidance Source	Bloomfield (2017, interview); Carollo (2017, interview); Mills (2017, interview); Rainey (2017, interview); USDA (2018)

3.8.2 LOCAL, PROVINCIAL, AND NATIONAL LAWS, REGULATIONS AND PERMITTING PERTAINING TO BIOMASS

Rationale	Feedstock whose production is directly dependent on local, provincial/state or national laws or government regulations can pose greater long-term risk than feedstock that is not, since laws and regulations may be subject to amendment or repeal. If utilization of biomass requires specific permits (i.e., percentage removal of forest residues or corn stover, allowable cut limits, air emission, storage permits, rights-of-way, overweight permits for trucks, cross-border permitting for shipment of biomass, chain of custody, or certification of sustainability) then likelihood of obtaining such permits and/or complying with permitting requirements should be examined.
Reporting	**Reporting Requirements** 1. Proponent shall indicate direct feedstock supply dependencies on laws, regulations or permits. 2. Proponent shall assess the likelihood and impact of change of such laws, regulations on feedstock supply, including those related to: • Forest harvesting • Air quality/emissions • Land-use change regulations • Traffic, noise, odor, dust • Wildlife protection 3. Proponent shall assess the likelihood of ability to obtain necessary permits.
Guidance	**Guidance for Reporting Requirement 1** Direct dependencies shall be those laws, regulations or permits which directly impact a Proponent's ability to procure, transport, trans-load, store, or utilize feedstock. They shall not include indirect dependencies such as laws that support markets for finished biofuels or biochemicals. Where Proponent's supply basins overlap multiple states/provinces, understanding of policies and guidelines in different state/provincial jurisdictions is necessary. A comprehensive description of all US national legislative, regulatory, and policy efforts can be found in Table 1-1 of the Bioenergy Technologies Office Multi-Year Program Plan (2016).

	The specific regulations that govern the production of a given feedstock should be evaluated and estimates made for the impacts of production on multiple resource concerns (including those that may have specific regulations). A plan for applying best practices to address all regulatory requirements should be formulated. Such an approach is described in CAAFI's *Feedstock Readiness Level Tool* (CAAFI 2018). **Guidance for Reporting Requirement 2** Certain jurisdictions have a history of changing regulations relevant to biomass. Such a history can indicate potential policy uncertainty. Proponent should conduct a thorough analysis of historical policy change in the supply basin. **Forest Harvesting.** Government regulations/restrictions exist restricting the amount of forest thinning and logging residues that can be removed from national forests and the number of agricultural residues that can be removed from a field. If a Proponent is reliant on these sources for its supply of feedstock it shall document the provisions under applicable government regulations that allow harvesting of targeted feedstocks. This includes caps on amounts that may be harvested, and allowable harvesting schedules and frequencies. **Air Quality/Emissions.** Proponent shall demonstrate understanding of local regulations relating to air quality and emissions, specifically in terms of risks regarding usage of the intended feedstock. **Land-Use Change Regulations.** Where Proponent feedstock requires land-use change (e.g., energy crop production) Proponent shall determine whether existing (and potential) regulations or policies relating to land-use change may impede access to feedstock (Kaffka 2018). **Traffic, Noise, Odor, Dust.** Proponent shall demonstrate understanding of local regulations relating to traffic, noise, odor and dust, specifically in terms of risks regarding usage of the intended feedstock. These issues are especially important when Proponent operates or intends to operate a pre-processing facility (e.g., chipping or grinding wood fibre). **Wildlife regulations.** Proponent shall determine whether existing (and potential) wildlife protection regulations may impede access to feedstock. For example, some wildlife regulations forbid forestry harvesting activities when an endangered species is detected. Policies pertaining to wildlife can also change over time, increasing policy instability for the project (Kaffka 2018).
Guidance Source	CAAFI (2018); Evans et al. (2013); Howard (2018, interview); Howes (2018, interview); Kaffka (2018, interview); Mills (2017, interview); Solomon (2018, interview)

3.8.3 BACKLASH AGAINST BIOMASS DEVELOPMENT, PROCUREMENT OR USAGE IN THE REGION

Rationale	Public backlash against biomass development in the Proponent region can directly impact Proponent's ability to procure, transport, trans-load, store, or utilize feedstock by affecting local policies, regulations and Proponent's ability to obtain necessary permitting.
Reporting	**Reporting Requirements** 1. Likelihood of potential backlash against biomass development in the region shall be assessed. **Reporting Recommendations** 1. In case of likely potential backlash against biomass development, a mitigation and communications plan should be developed in conjunction with the local community.
Guidance	**Guidance for Reporting Requirement 1** Historical occurrence of material public backlash against biomass development in the region, if any, shall be flagged by Proponent. If historical backlash has occurred, Proponent shall assess likelihood and impact of any current risk. If no historical backlash occurred, Proponent shall assess the likelihood of such backlash at present. **Guidance for Reporting Recommendation 1**

	In the case of backlash being deemed a significant risk, Proponent shall prepare and execute a communications plan to educate residents and environmental groups about the range of benefits deriving from the Proponent project, including: • Direct Benefits (e.g., plant operation expenditures and employment) • Indirect Benefits (e.g., forest or soil health) • Induced Benefits (e.g., household spending by direct and indirect employees). Demonstrate sustainability of biomass resource processed by the project. For woody biomass, demonstrate Proponent's positive effect on forest health and acquire certification if such exists (e.g., Sustainable Biomass Partnership certification for wood-based projects). In circumstances where biomass projects have been determined to have community and social benefits, these benefits should be promoted and made clear. For example, Marinescu (2016) has demonstrated the potential for heat and/or electricity plants using logging and sawmill residues in specific British Columbia communities to generate substantial local sustainability benefits. **Agricultural residues.** There are no certifications currently in place for agricultural biomass. Data available from literature sources or from bioenergy research at DOE or USDA labs could be used as source material to convey environmental benefits of agricultural biomass use over fossil fuels for energy production.
Guidance Source	Howes (2018, interview); Marinescu (2016); McGuire et al. (2017); VanEvery & Higgelke (2000)

3.8.4 CONSENT OF, AND CO-OPERATION WITH, INDIGENOUS COMMUNITIES AND FIRST NATIONS

Rationale	Where new project development on or near Indigenous or First Nation land, or where near Indigenous or First Nations exert influence over feedstock producing areas, consent of, and co-operation with, Indigenous communities and First Nations decreases Proponent risk.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate an understanding of any potential conflicts it may encounter with Indigenous land rights or First Nation communities. **Reporting Recommendations** 1. In cases where feedstock is procured from Indigenous lands, or where Indigenous communities exert influence over lands, the project should ensure that the Indigenous community has been consulted and have expressed consent.
Guidance	**Guidance for Reporting Recommendation 1** If feedstock is sourced from Indigenous and First Nation land, it shall respect the traditions and culture of Indigenous and First Nation communities. An RSB Water Assessment may be necessary for addressing water issues related to Indigenous lands. **Water Management & Demonstrating Respect for Indigenous Rights (Section 9a, RSB 2016):** • The use of water for feedstock operations should not be at the expense of the water needed by the communities that rely on the same water source(s) for subsistence. • The project should assess the potential impacts of the operations on water availability within the local community and ecosystems during the screening exercise of the impact assessment process and mitigate any negative impacts. • Water resources under legitimate dispute shall not be used for feedstock operations until any legitimate disputes have been settled through negotiated agreements with affected stakeholders – following a free, prior, and informed consent enabling process. • Respect and protect all formal or customary water rights that exist through the Environmental and Social Management Plan (ESMP) to prevent infringement on such rights. No modification of the existing rights can happen without the free, prior and informed consent (RSB Standards 2a) of the parties affected.

Guidance Source	RSB (2016)

3.9 Risk Factor: Greenhouse Gas (GHG) Accounting System

3.9.1 GHG EMISSIONS FROM PRODUCTION, HARVEST AND TRANSPORT

Rationale	Understanding a project's overall emissions and the carbon intensity throughout the feedstock supply chain is an essential part of reducing risks related to carbon pricing mechanisms and related regulations GHG emissions from production, harvest and transportation can be a significant challenge to Proponent claims of carbon neutrality for biomass projects. Carbon emissions from harvested soils, as well as emissions from harvesting machinery or delivery trucks, can make the achievement of net-zero GHG emissions difficult. If a Proponent's financial model relies on carbon neutrality/GHG regulatory pricing frameworks, then an investigation into the feedstock's carbon emission status is essential.
Reporting	**Reporting Requirements** 1. Proponent shall assess the degree to which GHG footprint of feedstock supply chain constitutes risk. 2. In case of likelihood of risk pertaining directly to the GHG footprint, GHG emissions from each component of the supply chain shall be quantified. **Reporting Recommendations** 1. Opportunities for optimized harvesting and/or use of renewable energy in the harvesting process may reduce the overall operational GHG footprint.
Guidance	**Guidance for Reporting Requirement 1** GHG emissions profiles for agricultural and forest residues are significantly different. Annual or semi-annual agricultural harvests means that carbon uptake by biomass may reasonably match carbon release in bioenergy systems within a short time frame. In forest biomass the uptake can range from 60-100 years, resulting in significant net GHG release into the atmosphere over that period of time (MacKechnie et al. 2011). To comprehensively evaluate the GHG footprint of a project, the evaluation method should employ a Life Cycle Assessment (LCA) (MacKechnie et al. 2011). If the project results in the conversion of a forest into agricultural lands (either directly as part of the project, or indirectly resulting from agricultural land being diverted to bioenergy), then there would be a large increase in carbon emissions resulting from the conversion (Layzell 2019). Examples of research papers looking at this issue can be found in Bentsen (2017) and Madsen and Bentsen (2018). **Agricultural Residue.** Residual biomass removal from agricultural production can result in increased exposure of agricultural soils to wind and water erosion leading to increased GHG emissions and carbon loading into the atmosphere (Nair et al. 2017; 2018a, b). To minimize carbon impacts from residue removal, Nair et al. (2017; 2018a, b) incorporate soil and carbon loss caps in their models to control the quantity of residues that can be removed from a site. To manage the reduction in residue biomass because of these caps, they recommend the conversion of non-profitable subfields producing corn and other row crops in the Midwestern US to energy crop subfields. **Forestry Biomass**. Many jurisdictions consider forest biomass as carbon neutral. However, research indicates that the carbon footprint of forest residues is significant (MacKechnie et al. 2011). When evaluating the GHG footprint of a project, the Proponent should take both scenarios

	into account. This would provide a more realistic picture of the carbon footprint, allowing the Proponent to understand GHG emission risks better in the face of potentially changing legislation. LCI/Forest Carbon Model is a framework developed by MacKechnie et al. (2011). It is recognized as a credible methodology for objectively assessing GHG emissions of forest bioenergy projects (Ter-Mikaelian 2019, feedback). A similar methodology has been described by Ter-Mikaelian et al. (2015). **Guidance for Reporting Recommendation 1** GHG mitigation practices such as controlled harvesting of corn stover to minimize erosion, and growing energy crops on soils with high erodibility and leaching capacity have been highlighted as alternate strategies to reduce GHG emissions. Farm equipment typically runs on fossil fuels, which have high GHG footprints. Opportunities to use renewable energy to power farm equipment should be investigated to reduce the additional GHG footprint.
Guidance Source	Bentsen (2017); Bonner et al. (2016); Kaffka (2018, interview); Layzell (2019, feedback); Madsen and Bentsen (2018); MacKechnie et al. (2011); Nair et al. (2017; 2018a, b); Ter-Mikaelian et al. (2015); Ter-Mikaelian (2019, feedback); Layzell (2019, feedback); Bi (2019, feedback)

3.9.2 POLITICAL AND REGULATORY UNCERTAINTY RELATED TO GHG EMISSIONS

Rationale	Carbon pricing systems are still emerging and vary substantially from province to province, and state to state. Political policies surrounding GHG emissions and climate change action plans are often contentious, and therefore at risk of changing with election cycles. Regulatory policies and their likelihood of change should be well understood with respect to available offset credit programs that could provide financial opportunities or pose risk.
Reporting	**Reporting Requirements** 1. Proponents shall evaluate and estimate all political and regulatory risks with which their operation is subject, relating to GHG emission accounting systems and pricing mechanisms. **Reporting Recommendations** 2. If necessary and reasonable, Proponents should take steps to mitigate the impacts of external GHG emissions legislation by internally pricing their emissions in order to maintain accounting stability.
Guidance	**Guidance for Reporting Requirement 1** These estimations can be made based on historical analyses of relevant political stances in applicable jurisdictions, and the frequency with which they change. For example, some businesses in the province of Ontario were subject to a carbon pricing scheme through the provincial cap-and-trade program from 2017 – 2018, before the program was cancelled by the newly elected provincial government. In 2019 however, the federal government of Canada implemented a national carbon pricing requirement that exposed Ontario businesses to carbon pricing once again after only a short hiatus from the provincial program. Further, 2019 will also see a federal election that will once again bring carbon pricing into question, potentially altering the carbon pricing policies that Ontarians are exposed to for a fourth time in less than 2 years. **Guidance for Reporting Recommendation 1** Internal pricing can stabilize a project's financial accounting in the long-term by reducing their exposure to the risks associated with changing or uncertain policies. Internal pricing can take several forms, including Shadow Pricing and Implicit Pricing. Shadow Pricing is the implementation of an internal emissions price based on schemes/prices that are forecasted to come into effect. Implicit Pricing is the marginal abatement cost of emissions reduction measures that the business already has in place to reduce their GHG footprint; for example, energy efficiency projects (Ahluwalia 2017).
Guidance Source	Ahluwalia (2017); Layzell (2019, feedback); Bi (2019, feedback)

3.9.3 GHG ACCOUNTING METHODS

Rationale	Where carbon emissions incentives exist (e.g., a carbon tax), biomass utilization can be economically viable. If alternative carbon emissions accounting systems are required or sanctioned, a different calculation of the carbon footprint of biomass can make feedstock (or the project as a whole) uneconomic. Use of a recognized GHG Accounting Framework can mitigate risk.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of the degree to which supply chain GHG footprint constitutes risk. 2. In case of likelihood of risk pertaining directly to the GHG footprints, GHG emissions of Proponent supply chain shall be quantified using a recognized industry framework.
Guidance	**Guidance for Reporting Requirement 1** Use of Global Warming Potential (GWP) is recommended to determine GHG profile of feedstock. GWP is an index describing the greenhouse gas emissions potential of various emissions. It was developed to allow comparisons of the global warming impacts of different gases. The index is based on CO2, meaning CO2 from fossil fuels have a GWP of 1.0. Where biomass is considered carbon neutral, the GWP is 0. Recent studies find that the GWP for biomass should be more than 0 (e.g., Booth (2018); Holtsmark (2013)), and could be 0.4 or more (Layzell (2019, feedback)). The Roundtable for Sustainable Biomass (RSB) standards is one scheme (among several) that contains methods for calculating and ensuring carbon neutrality. Several options for reporting on the lifecycle of GHG emissions of biomass are: • RSB GHG Calculation Methodology by using the RSB Calculation Tool or by carrying out an individual calculation • BioGrace GHG calculation tool • Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, developed and maintained by the Argonne National Laboratory (ANL) Ter-Mikaelian at el. (2015) describes common carbon accounting assumptions and their relevance to carbon accounting systems. Carbon modelling and quantification in a biomass supply chain should take account of locations (i.e., each geography will likely have different outputs) and land use changes. MacKechnie et al. (2013) describe an integrative framework intended to create a better understanding of net carbon emissions.
Guidance Source	Booth (2018); Gillenwater (2012); Holtsmark (2013); Kaffka (2018, interview); Layzell (2019, feedback); Moroni et al. (2015); Yemshanov et al. (2018b); (RSB 2016); MacKechnie et al. (2011); Ter-Mikaelian et al. (2015); Ter-Mikaelian (2019, feedback); Layzell (2019, feedback)

Category 4.0: Feedstock Quality

4.1 Risk Factor: Feedstock Quality

4.1.1 CONSISTENCY OF FEEDSTOCK QUALITY REQUIREMENTS WITH LOCAL AVAILABILITY

Rationale	If specifications of biomass feedstock do not reflect what is currently or historically produced in the supply basin, supply chain resiliency decreases and risk increases.
Reporting	**Reporting Requirements** 1. Proponent feedstock specifications shall be consistent with feedstock quality widely available in the supply basin. **Reporting Recommendations** 1. Where feedstock specifications are not typical, mitigating factors shall be demonstrated.
Guidance	**Guidance for Reporting Requirements 1** Suppliers often supply more than one market and, despite contracting for a stricter specification, may deliver traditional feedstock specifications (i.e., sub-standard) that are acceptable for existing markets. That is, some suppliers may believe that the Proponent will in fact tolerate the typical regional specification despite written contract specifications to the contrary. Thermochemical and biochemical refineries have different requirements for the quality of feedstock used for producing fuels or energy. Quality parameters include ash, moisture and hydrocarbon contents (e.g., sugar, lignin, etc.). Current fast-pyrolysis and hydrotreating biofuel facilities require feedstock with low ash content (~0.9%, on a dry basis), 30% moisture content and ~50% hydrocarbons (Jones et al. 2013). For biochemical conversion of feedstocks to biofuels, current designs require 5% ash content on a dry basis, 20% moisture content, and total structural carbohydrates at 59% (Davis et al. 2013). As technologies develop, these requirements will get more specific and optimal quality range parameters will become clearer. It is important for a Proponent to be aware of changing requirements and compare them to the available feedstock quality parameters.
Guidance Source	Abt (2018, interview); Davis et al. (2013); Jones et al. (2013); Muth (2017, interview); Spikes (2017, interview); Smith (2017, interview); Tumuluru (2016)

4.1.2 DENSIFICATION AND PRE-PROCESSING[1]

Rationale	Non-homogeneity of feedstock can be a major risk during plant scale-up. Densification and pre-processing of feedstock can de-risk scale-up by reducing feedstock variability through size reduction, drying, ash removal, densification, pelletization, or other unit operations to convert to feedstock or required quality, shape and other specifications. Projects relying upon pre-processing (particularity in the form of pellets with consistent physical and chemical properties and high durability) have fewer quality, homogeneity and flowability issues.
Reporting	**Reporting Requirements** 1. The type of pre-processing and densification used shall be identified (i.e., baling, pelletizing or briquetting), including whether densification or pre-processing is done by suppliers or Proponent, and the types of equipment used. 2. Proponent shall verify steady operation of all steps of the pre-processing operation at scale.

[1] *NOTE: Risk Factor is also used in Feedstock Scale-up Risk due to relevance.*

	3. The bounds of variability of key quality specification variables post-pre-processing or densification shall be identified. 4. The ratio of densified or pre-processed feedstock to natural feedstock shall be determined and such ratios shall be shown to be suitable and appropriately applied to the Proponent.
Guidance	**Guidance for Reporting Requirement 3** Densification has been tested for numerous feedstocks with different physical and chemical properties at Idaho National Laboratory (INL) (Tumuluru 2018). Results are available to the public.
Guidance Source	Solomon (2019, interview); (Tumuluru (2018, interview)

4.1.3 FEEDSTOCK DEGRADATION

Rationale	Dry matter is important for bio-processes and losses of such typically results in lower product quality or less product being produced. Incorrect or insufficient information on feedstock degradation during storage can lead to the overestimation of quantities, quality or cost of available feedstock.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of dry matter losses in feedstock during storage. **Reporting Recommendations** 1. If feedstock is stored at suppliers' facilities, an understanding of suppliers' storage methods and its effect on feedstock degradation should be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** In general, feedstock stored indoors has a lower rate of degradation than feedstock stored outdoors. **Agricultural Residues.** Historical data indicate that corn stover stored outdoors results in higher dry matter losses than when stored indoors, with considerable variability depending on moisture content and storage conditions. Richey et al. (1982) reported dry matter loss increases from 10% up to 23% upon outdoor storage of baled stover. Shinners et al. (2007) reported average dry matter losses of 3.3% for dry stover bales stored indoors and 18.1% for dry stover bales stored outdoors after 8 months, with that figure adjusting to 10.0%, 13.9% and 30.4% when bales were stored outdoors using net wrap, plastic twine and sisal twine, respectively. Emery and Mosier (2012) summarize dry matter losses from a number of publications and report that among baled hay and corn stover stored indoors, the dry matter losses were consistently less than 6% compared to losses between 10% and 20% from bales stored outdoors and baled under a 20% moisture threshold. Occasionally, losses are reported as high as 35-40%. They also summarize the results from various studies statistically into percentile values for indoor and outdoor dry storage. Shah et al. (2011) report dry matter losses from bales stored outdoors of 5-11% and 14-17%, with tarp and breathable film covers, respectively. Shinners et al. (2007) report about 3% loss in ensiled storage of wet stover. Emery and Mosier (2012) summarize the dry matter losses from wet storage using data from multiple studies into distribution with a 90% confidence interval of 2.8% and 20.6%, and a median of 7.8%. Athmanathan (2013) provides a detailed analysis of experimental results on the impacts of moisture content and temperature on dry matter loss from corn stover, switchgrass and sweet sorghum bagasse. His research indicated threshold temperatures and moisture contents below which there was little degradation. It also showed that increasing temperatures up to 35°C resulted in increased dry matter loss along with increases in moisture content above 20%. Feedstock degradation in storage can be mitigated by a plant's ability to procure feedstock just-in-time. This requires maximizing the time in a year during which feedstock can be harvested and delivered to the plant. This can be achieved through expanding harvesting seasons by allowing a mix of feedstock types (e.g., agricultural with woody materials), or processing feedstock that can be harvested year-round.

	Energy Crops. Mooney et al. (2012) estimated dry matter losses for switchgrass, canary grass and sorghum from multiple sources. For outdoor storage of switchgrass, they report dry matter loss from 8.2-13.0%; for canary grass and switchgrass, 15%; for sorghum and switchgrass, 8.2-13.0%; and for sorghum 18%. For indoor storage, they report dry matter loss for switchgrass of less than 2%-3%; for canary grass and switchgrass, 3%; for sorghum and switchgrass, 4.7-5.6%; and for sorghum 10%. For switchgrass stored in rectangular bales in Tennessee, they report 90.8% dry matter loss outdoors and 15% indoors
Guidance Source	Athmanathan (2013); Dujmovic (2019, feedback); Ebadian et al. (2011); Emery & Mosier (2012); Gebreslassie et al. (2012); Lamers et. al. (2015a); Mooney et al. (2012); Nguyen (2017, interview); Richey et al. (1982); Shah et al. (2011); Shinners et al. (2007)

4.1.4 QUALITY MEASUREMENT METHODS

Rationale	In order to understand feedstock quality; moisture content, ash content and other specifications have to be measured accurately. Measurements need to be based on recognized testing and sampling procedures which should be specified and followed by the Proponent.
Reporting	**Reporting Requirements** 1. Feedstock quality sampling and measurement methods shall be clear and consistent with industry standards. **Reporting Recommendations** 1. Suppliers' acceptance of sampling and measurement methods shall be demonstrated.
Guidance	**Guidance for Reporting Requirement 1** Three general categories of sampling and measurement techniques have been developed by Idaho National Laboratory (INL). The first methods use cylindrical core samples from bales, however this constitutes an invasive process. The second method uses a probe to directly measure and report moisture at different locations within a bale. The third process uses microwaves to obtain moisture distributions at a resolution of one inch. **Agricultural Residue and Energy Crops.** It is important to know both the average values for various biomass quality parameters (e.g., moisture and ash content) as well as the variances from the averages in a consignment of bales. However, inherent heterogeneity associated with moisture and ash content distributions within bales makes this difficult. Moisture content can change as climatic conditions such as humidity and temperature influence the moisture movement and evaporation/condensation processes differentially. Therefore, the credibility of sampling and measurement techniques is critical.
Guidance Source	Abt (2018, interview); Smith (2017, interview); Spikes (2017, interview)

4.1.5 GEOGRAPHIC LOCATION INFLUENCE ON FEEDSTOCK VARIABILITY

Rationale	Feedstock from different regions may differ in quality due to variations in soil quality, topography, harvest practices, weather, fertilizer applied, etc.
Reporting	**Reporting Requirements** 1. Proponent shall demonstrate understanding of geographic regions from which feedstock will be sourced, and the effect on feedstock quality.
Guidance	**Guidance for Reporting Requirement 1** Because of the variability associated with supply from multiple regions, blending or pre-processing may be required to attain the desired raw material specifications.

	Variability in herbaceous feedstock quality parameters is typically much higher than in woody feedstocks. Blending of herbaceous materials to produce a single feedstock with a narrow range of desired quality parameters is therefore a bigger challenge than with woody feedstocks.
Guidance Source	Spikes (2017, interview); Swan (2018, interview)

4.2 Risk Factor: Specific Feedstock Quality Variables

4.2.1 VARIABILITY IN MOISTURE CONTENT

Rationale	Some degree of moisture content variability is unavoidable. Accurate bounds of moisture variation within feedstock should be known. Feedstock with high moisture variation can pose a risk of fire, as well as create operational risks associated with delayed processing (e.g., grinding and/or clogging).
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Moisture content variation typical in available feedstock 2. Factors that influence moisture content variability 3. Mitigation strategies to control impact of moisture content variation.
Guidance	**Guidance for Reporting Requirement 1** Proponent should determine upper and lower limit of acceptable moisture content in feedstock. Cross-reference these limits with feedstock moisture content data acquired from sampling. The vast majority of the variation (i.e., 95-99%) should be within the upper and lower limit (Ecostrat 2017). INL's Bioenergy Feedstock Library (BFL) and ORNL's Knowledge Discovery Framework (KDF) are valuable resources to understand the spatial and temporal variabilities in moisture content and other properties of feedstock. Main factors affecting moisture content variability are harvest timing, age, type of biomass, region of origin, water availability and irrigation practices. **Guidance for Reporting Requirement 2** The integrity of the tarps used to cover feedstock during storage is important. Tarps are prone to friction and damages due to atmospheric conditions. Using a high-quality tarp lowers the risk of tarp damage and therefore moisture movement throughout the bale. **Guidance for Reporting Requirement 3** Driers on Proponent site are effective mitigants against moistures risks.
Guidance Source	Ecostrat (2017); Nguyen (2017, interview); Smith (2017, interview); Spikes (2017, interview); Tumuluru (2016); Webster (2017, interview)

4.2.2 VARIABILITY IN ASH CONTENT

Rationale	Some degree of ash content variability is unavoidable. Accurate bounds of ash variation within feedstock should be known. Feedstock with high ash variation can pose a risk of throughput requirements as well as additional costs associated with removing ash from the system.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Typical ash content variation in available feedstock 2. Factors that influence ash content variability 3. Mitigation strategies to control impact of ash content variation.

Guidance	**Guidance for Reporting Requirement 1** Proponent should determine upper and lower limit of acceptable ash content in feedstock. Cross-reference these limits with feedstock ash content data acquired from sampling. The vast majority of the variation (i.e., 95-99%) should be within the upper and lower limit (Ecostrat 2017). INL's Bioenergy Feedstock Library (BFL) and ORNL's Knowledge Discovery Framework (KDF) are valuable resources to understand the spatial and temporal variabilities in ash content and other properties of feedstock. **Guidance for Reporting Requirement 3** Consistent low ash content in harvested biomass can be maintained by using methods such as washing, leaching and acid or alkali pretreatment. Limitations of these pre-processing steps can be associated with equipment and chemical costs, but these costs can be offset by reducing the operational costs of bio-refineries because the pre-treatments can result in lower maintenance costs (Tumuluru et al. 2016b).
Guidance Source	Ecostrat (2017); Spikes (2017, interview); Tumuluru et al. (2016a); Tumuluru (2016)

4.2.3 VARIABILITY IN PARTICLE SIZE

Rationale	Some degree of particle size variability is unavoidable. Accurate bounds of particle size variation within feedstock should be known. Large variations in particle size and texture result in the need for multiple size reduction techniques.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Size variation typical in available feedstock 2. Factors that influence size variability 3. Mitigation strategies to control impact of size variation.
Guidance	**Guidance for Reporting Requirement 1** Proponent should determine upper and lower limit of acceptable particle size in feedstock. Cross-reference these limits with feedstock particle size data acquired from sampling. The vast majority of the variation (i.e., 95- 99%) should be within the upper and lower limit (Ecostrat 2017). Feedstock plant species, management practices and time of harvest play significant roles in controlling the shape and size of particles supplied as feedstock. INL's Bioenergy Feedstock Library (BFL) and ORNL's Knowledge Discovery Framework (KDF) are valuable resources to understand the spatial and temporal variabilities in particle size and other properties of feedstock. **Guidance for Reporting Requirement 3** Variability in particle size arise from multiple sources and multiple locations along the supply chain. Screeners and grinders on Proponent site are effective mitigants against sizing risk. Alternative to pelletization, particularly for herbaceous biomass, is the use of unit operations such as drying and grinding. These operations can be used to produce particles with desired maximum sizes. However, the size distribution below the maximum size could still have large variability and therefore pose multiple challenges at bio-refineries.
Guidance Source	(Tumuluri 2018, interview)

4.2.4 VARIABILITY IN CHEMICAL CONTENT

Rationale	Some degree of variability in the chemical content of feedstock is unavoidable. Accurate bounds of chemical content variation within feedstock should be known. High variability in chemical contents in feedstock (e.g., lignin, carbohydrates, sugar, etc.) increases the likelihood that feedstock will not be optimal for a conversion process.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Chemical content variation typical in available feedstock 2. Factors that influence chemical content variability 3. Mitigation strategies to control impact of chemical content variation.
Guidance	**Guidance for Reporting Requirement 1** Carbohydrate and lignin content are important in the conversion of ligno-cellulosic material into biofuels through biochemical conversion processes. While carbohydrates are converted to biofuels, lignin functions as a recalcitrant. In thermochemical conversion, both lignin and carbohydrates are available for thermal conversion and power production. INL's Bioenergy Feedstock Library (BFL) and ORNL's Knowledge Discovery Framework (KDF) are valuable resources to understand the spatial and temporal variabilities in chemical content and other properties of feedstock. **Guidance for Reporting Requirement 3** Pelletization can have a positive effect on the control of feedstock chemical content variability.
Guidance Source	Dujmovic (2019, feedback); Tumuluru et al. (2016a); Tumuluru (2016)

4.2.5 FEEDSTOCK BALE DENSITY

Rationale	High density bales of feedstock can decrease transportation costs, but density can cause problems during pre-processing. Bale density has been linked with feedstock issues such as low flowability, clogging, slow-down and equipment shut downs, particularly when it is associated with high moisture and/or ash contents. It has also been linked to sampling issues when probe samples cannot pierce bales due to high density.
Reporting	**Reporting Requirements** 1. Risks related to feedstock bale density shall be assessed and an optimal bale density established. 2. Availability of feedstock at optimal bale density shall be established.
Guidance	**Guidance for Reporting Requirement 1** Bale density has an impact on road weight; the higher the density, the heavier the road weight. Most regions have upper weight limits on roads. If bale density causes trucks to exceed weight limits, or to run at less than cubic capacity, then bale density should be re-examined.
Guidance Source	Spikes (2017, interview)

Category 5.0: Feedstock Scale-Up Risk

5.1 Risk Factor: Feedstock Scale-Up

5.1.1 FEEDSTOCK QUALITY AT PRODUCTION SCALE

Rationale	The physical and chemical properties of feedstock used in lab, pilot and field testing can fail to be representative of feedstock generated by large-scale operations. It is important to conduct tests on feedstock representative of that which will be produced by large-scale operations. Failure to adequately test the full range of parameter values can result in severe problems during scale-up.
Reporting	**Reporting Requirements** 1. Lab and field tests should utilize feedstock that accurately represents feedstock variability of scale operations. Experimental design for field-scale tests should reflect all ranges of individual, and combination of, parameter values being tested.
Guidance	**Guidance for Reporting Requirement 1** Document all sampling methodology, samples and ranges used, test conditions and results, as evidence for viable scale-up.
Guidance Source	Nguyen (2017, interview); Smith (2017, interview)

5.1.2 CAPACITY OF SUPPLY CHAIN COMPONENTS AND INFRASTRUCTURE TO SCALE

Rationale	Scale-up risk increases if supply chain components, or underlying feedstock infrastructure necessary for these components, cannot scale to handle Proponent feedstock requirements and throughput capacity. Capacity to scale should be demonstrated.
Reporting	**Reporting Requirements** Proponent shall demonstrate that: 1. Throughput rates and efficiencies of each supply chain component are adequate for proposed plant scale 2. Necessary underlying infrastructure component capacities are adequate for proposed plant scale. **Reporting Recommendations** 1. The plant size and design should be optimized with the feedstock availability.
Guidance	**Guidance for Reporting Requirement 1** Supply chain components should include (as applicable) planting, harvesting, densification, pre-processing, storage and transport. Pre-processing refers to mechanical or chemical processes in which biomass may undergo size reduction, drying, ash removal, densification or other operations to convert feedstock to required quality, shape and other specifications. **Guidance for Reporting Requirement 2** Underlying infrastructure components should include (as applicable) land base, roads, equipment, labor, weather, regulatory and social environments. **Guidance for Reporting Recommendation 2** Proponent plant size should be aligned with the feedstock availability and other relevant factors. According to Miao et al. (2013), feedstock pre-processing, and supply and storage systems need to be aligned with the biofuel plant size and its choice of pre-treatment and conversion technology, as well as the feedstock type, geography and climate.

	Large-scale operations run higher risks of feedstock delivery because of potential shortage of trucks and drivers, higher costs of satellite storage, and multiple handling steps (Nguyen 2018). Based on the feedstock throughput rate and bio-refinery processes, computer-based models can be used to size, design and cost the bio-refinery operation (see models developed by Gebreslassie et al. (2012) and Chen et al. (2012)).
Guidance Source	Chen et al. (2012); Gebreslassie et al. (2012); Malik (2017, interview); Miao et al. (2013); Passmore (2017, interview); Solomon (2019, interview)

5.1.3 ROLE OF DENSIFICATION AND PRE-PROCESSING[2]

Rationale	Non-homogeneity of feedstock can be a major risk during plant scale-up. Densification and pre-processing of feedstock can de-risk scale-up by reducing feedstock variability through size reduction, drying, ash removal, densification, pelletization, or other unit operations to convert feedstock to required quality, shape and other specifications. Projects relying upon pre-processing (particularity in the form of pellets with consistent physical and chemical properties and high durability) have fewer quality, homogeneity and flowability issues.
Reporting	**Reporting Requirements** 1. The type of pre-processing and densification shall be identified (e.g., baling, pelletizing or briquetting) including whether densification or pre-processing is done by suppliers or Proponent, and types of equipment used. 2. Proponent shall verify steady operation of all steps of the pre-processing operation at scale. 3. The bounds of variability of key quality specification variables post-pre-processing or densification shall be identified. 4. The ratio of densified or pre-processed feedstock to natural feedstock shall be determined, and such ratios shall be shown to be suitable and appropriately applied to the Proponent.
Guidance	**Guidance for Reporting Requirement 1** Densification and pelletization for different herbaceous biomass types at different moisture contents have been successfully tested at INL. INL has shown the efficacy of producing pellets at moisture contents ranging from 10-30% using corn stover. **Guidance for Reporting Requirement 3** Densification has been tested for numerous feedstocks with different physical and chemical properties at Idaho National Laboratory (INL) (Tumuluru 2018). Results are available to the public.
Guidance Source	Dujmovic (2019, feedback); Solomon (2019, interview); Tumuluru (2018, interview)

5.1.4 LAB-SCALE, PILOT-SCALE AND FIELD SCALE TESTING

Rationale	Where feedstock supply chains need to be developed, it is necessary to establish applicability, feasibility and practicality at commercial scale with lab-scale, pilot-scale and, preferably, field-scale testing.
Reporting	**Reporting Requirements** Proponent shall identify: 1. Results of lab-scale testing 2. Results of pilot-scale testing 3. Results of field-scale testing.

[2] *NOTE: Risk Factor is also used in Feedstock Quality Risk due to relevance.*

Guidance	**Guidance for Reporting Requirement 1** Edwards (2015) presents the stage-gate approach for scaling-up biofuel technologies from lab or bench-scale to commercial scales, and how the scaling factors in bioenergy applications differ from traditional chemical process industries. This is a valuable resource in understanding how the challenges related to handling solids and processing fluids in bioenergy processes can be addressed systematically from lab to commercialization. He identifies conditions under which scaling-up can occur directly from batch to commercial scale, and when scaling up should follow lab to pilot to demonstration to commercial-scale. **Guidance for Reporting Requirement 2** Lab or bench-scale testing should be followed by pilot-scale testing. Pilot-scale tests elevate the typical batch process under lab-scale to batch, semi-continuous, or continuous processes, as desired, and depending on the process being tested. Tests should ensure that consistency exists between lab and pilot-scales; that any cost estimates conducted at production levels are consistent with results from lab and pilot tests; and that assumptions made for scale-up are valid. Pilot-scale tests should mimic a real-application environment to the extent possible, and should elicit statistically significant results. **Guidance for Reporting Requirement 3** Pilot-scale testing shall be followed by field-scale demonstrations. Data should be collected to show evidence of feasibility of scale-up to operational level. Experimental designs for field-scale tests should be cognizant of variabilities in different parameters, and should reflect all ranges of individual and combined parameter values being tested. Failure to adequately test the full range of feedstock parameter values could result in severe problems during actual operations and increases in operating costs. For novel equipment used in the field or forest, manufacturers should be able to demonstrate the ability of the equipment to operat at the desired scale.
Guidance Source	Edwards (2015); Nguyen, (2017, interview)

5.1.5 FACILITY START-UP DELAYS

Rationale	If facility start-up does not take place in the timeline originally indicated to suppliers, supply contracts may be terminated or breached.
Reporting	**Reporting Requirements** 1. If start-up has been significantly delayed, Proponent shall demonstrate that supply contracts are still valid and that danger of breach or termination is nominal.
Guidance	
Guidance Source	Carollo (2017, interview); Nguyen (2017, interview)

Category 6.0: Internal Organizational Risks

6.1 Risk Factor: Feedstock Cost Margins

6.1.1 RED-LINE FEEDSTOCK COST

Rationale	The feedstock procurement “red-line” cost is the feedstock cost, above which Proponent is no longer able to maintain operations, or which will cause it to breach a financial covenant or warranty. In general, the greater the difference between the red-line feedstock cost and the maximum expected cost of feedstock over time (the “Feedstock Cost Margin”), the greater the Proponent’s ability to mitigate feedstock risk, and the lower the supply chain risk.
Reporting	**Reporting Requirements** 1. Proponent shall report red-line feedstock cost. 2. Proponent shall show a validated, statistically relevant analysis which represents the expected bounds of feedstock cost over time. 3. The difference between the red-line cost and 10% probability upper bound shall be determined. 4. The difference between the current market price for feedstock and the maximum price payable by the Proponent shall be determined. **Reporting Recommendations** 1. Proponent’s feedstock cost margin versus that of major competitors should be estimated.
Guidance	**Guidance for Reporting Requirement 2** Monte Carlo analysis is preferred. **Guidance for Reporting Recommendation 1** The benefits of a high red-line differential are reduced if similar differentials are enjoyed by competitors. For example, pulp and paper plant operations have been known to be able to dramatically increase prices paid for feedstock in times of shortages to mitigate supply chain disruptions. If both Proponent and competitors have a high red-line differential then a price war can result in times of shortage.
Guidance Source	Roberts (2018, interview); Smith et al. (2016); Volpe (2018b)

6.2 Risk Factor: On-site Inventory

6.2.1 FEEDSTOCK INVENTORY DAYS

Rationale	Feedstock inventory can be an effective mitigant of supply shortfall risk and temporary spot market price spikes for feedstock. In general, the quantity of on-site inventory maintained by the Proponent should be sufficient to act as a buffer against seasonal shortfalls and temporary supply disruptions. There is no standard or best-practice number of inventory days.
Reporting	**Reporting Requirements** 1. Proponent shall produce a schedule showing monthly feedstock inventory quantities maintained. 2. Inventory schedule shall be supported by an analysis detailing historical availability and price of feedstock in the case of existing supply chains. 3. Inventory schedule shall be supported by sensitivity modelling to anticipated disruption events affecting availability and price of feedstock in the case of greenfield supply chains. **Reporting Recommendations** 1. Inventory capacity of major competitors should be known and compared to Proponent inventory capacity.

Guidance	**Guidance for Reporting Requirement 1** Satellite storage yards shall count as on-site inventory if such yards are controlled by Proponent. There is no standard or best-practice number of inventory days. The optimal number of feedstock inventory days differs by region and feedstock type, and depends on the influence of many factors impacting feedstock availability and price. These include: regional climate, regular seasonal impacts (e.g., seasonal road weight restrictions), irregular weather impacts (e.g., excessive rain or cold), supplier reliability, supply redundancy and local competition, among others. **Woody Biomass.** Expert opinion on ideal inventory capacity days differs: Baylies (2017) suggests that the minimum number of days of inventory capacity should be 14 in high-availability seasons, and preferably at least 30 days in regular-availability seasons. O'Leary (2017) suggests maintaining inventory above 7 days in good seasons, and at least 30 days in wet seasons. On the other hand, Jenkins (2017) argues that the minimum inventory level should be 60 days in high-availability seasons, and six months in low-availability seasons. Rainey (2017) says that 45-60-day inventory is typically what is necessary to run a plant smoothly. **Agricultural Residues.** It has been recommended that inventory management plans strive to maintain an inventory of 180 days, with an expectation that 90% of this would be viable as feedstock (Mills 2017). Genera Energy's biomass inventory management fundamentals are cited as an example of best-of-kind inventory management practices (Genera 2017). **Guidance for Reporting Requirement 2** At least 5 years of historical data is recommended. **Guidance for Reporting Requirement 3** Anticipated temporary disruption events that should be modeled are: regional climate, regular seasonal impacts (e.g., seasonal road weight restrictions), irregular weather impacts (e.g., excessive rain, cold or fire), expected supplier breakdowns, and pressure by existing competition. A reasonable factor for expected supplier breach of feedstock quantity commitments should be incorporated. **Guidance for Reporting Recommendation 1** The ability to maintain inventory capacity greater than that required for plant operations can represent a competitive advantage; the ability to store greater amounts of inventory than the competition can enable the Proponent to continue to receive material in time of excess capacities when spot prices are low. Supplier relations are greatly enhanced by Proponents that continue to intake feedstock in times of excess capacity when competitors issue supply quotas.
Guidance Source	Baylies (2017, interview); Friesen & Volpé (2012); Genera Energy (2017); Huhnke (2017, interview); Jenkins (2017, interview); Mills (2017, interview); Nguyen (2018, comment); O'Leary (2017, interview); Parrish (2018, interview); Rainey (2017, interview); Ralevic et al. (2010); Volpé (2016b)

6.2.2 INVENTORY DEGRADATION AND CONTAMINATION

Rationale	Feedstock degradation of on-site inventory can be a major source of supply chain risk; dry matter loss, decomposition, moisture gain, and changes to chemical composition can drive Proponent cost and render feedstock unsuitable for further processing.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Expected feedstock changes and/or degradation during inventory including at least: • Moisture • Decomposition • Chemical composition

	• Temperature (in relation to ignition temperature points) • Dirt and other contamination from ancillary sources (e.g., blowing plastics) or the ground (Tudman & Hvisdas 2018). 2. Optimal/maximum feedstock inventory storage time. 3. In cases where degradation is unavoidable, the bounds shall be mapped and potential impacts modelled, addressed and limited. **Reporting Recommendations** 1. Proponent should demonstrate understanding of industry best practices for minimizing feedstock degradation (e.g., first-in/first-out principles).
Guidance	**Guidance for Reporting Requirement 1** **Woody Biomass.** See Volpé (2016b) for information on drying rates of different wood species under various conditions. **Guidance for Reporting Recommendation 1** To mitigate the risk of feedstock degradation, internal storage is preferred. Agricultural feedstock may be stored in covered conditions such as warehouses or plastic tube silos. **Woody Biomass.** Publications that outline best practices for feedstock inventory management include Friesen & Volpé (2012) and Volpé (2016b). Where climate contains significant humidity, optimal feedstock pile management systems would not have piles stored for greater than one month. Beyond this time period, feedstock degradation begins to become salient (Friesen & Volpé 2012). **Agricultural Residue**. Feedstock should not be stored for more than one year; over time Agricultural Residues become more brittle which could lead to processing issues.
Guidance Source	An et al. (2011); Blunk et al. (2003); Cook (2018, interview); Dunnett et al. (2007); Ebadian et al. (2011); Friesen & Volpé (2012); Hamelinck et al. (2005); Howes (2018, interview); Huhnke (2018, interview); Jenkins (2017, interview); Kaffka (2018, interview); Marsollek (2018, interview); Nguyen (2017, interview); O'Leary (2017, interview); Mitchell (2017, interview); Rentizelas et al. (2009a, b); Searcy (2018, interview); Sims & Venturi (2004); Spikes (2017, interview); Tudman & Hvisdas (2018, interview); Uslu et al. (2008); Volpé (2016b)

6.2.3 INVENTORY FIRE

Rationale	Inventory fire due to spontaneous combustion or arson can result in significant feedstock loss, facility shut-down and financial impact.
Reporting	**Reporting Requirements** Proponent shall: 1. Monitor internal temperature of inventory piles to ensure consistent temperatures below self-ignition levels. 2. Not mix non-homogenous feedstocks within the same piles if risk of spontaneous ignition is determined to exist. If non-homogenous feedstocks are utilized, blending should take place before utilization. 3. Demonstrate internal policy governing how inventory piles are made (use of stackers, dozers or loaders), size limits of piles (length, width, height) and distance around/between piles and ensure that such methods limit impact of an ignition event. 4. Develop a fire response plan that outlines the likelihood and impact of ignition events, mitigation initiatives for such events (i.e., access to water, pile size, shape and spacing, fencing or security around piles, lightning rods) and describes the course of action in case of a combustion event.
Guidance	**Guidance for Reporting Requirement 2** Spontaneous combustion risk increases in large feedstock piles containing non-homogenous material in terms of moisture content and particle size and with high pile densities (due to

	stacking with a dozer or loader as opposed to a stacker). Risk of spontaneous ignition differs across biomass feedstock type; for example, the risk of fire in switchgrass is higher than in corn stover (Webb 2016). The shape of bales has an impact on the risk of fire. For example, lower density of round bales, as opposed to rectangular bales, permit more oxygen to be available to fire and after the wrap around a bale is burnt away, outer layers of round bales fell away exposing fresh material to the fire (Webb 2016). Reference data on the drying rates of different wood species under various conditions is available from FPInnovations (Volpé 2016b). **Guidance for Reporting Requirement 3** Feedstock inventory should be stored in smaller piles/stacks or in windrow type piles so that in case of fire, combusting elements are easily separable. This should be the case especially during the first two weeks of pile/bale storage when moisture content differences are most pronounced. FPInnovations has developed a best-practices system for woody biomass pile management that can be used by projects to mitigate pile related risks. This system recommends that piles be stored for <1 month and when located outdoors, that they be situated parallel to prevailing wind direction. **Guidance for Reporting Requirement 4** Friesen & Volpé (2012) demonstrate that piles with a moisture content between 20-50% are at risk of combustion, with the greatest risk being presented when moisture content is between 35-40%. Risk of spontaneous combustion is mitigated when feedstock has lower moisture content. For example, dry feedstock with moisture content of 15% or lower has negligible risk of spontaneous combustion. Best practices for reducing the risk of feedstock pile fires can be found in Friesen & Volpe (2012), McGill & Darr (2014) and Bessa & Block (2017). In cases where there is a high risk of arson or vandalism or where the impact of such events is high, it is recommended that feedstock be secured. Fencing may not be sufficient to prevent arson or vandalism. Risk of fire due to lightning can be mitigated by attracting lightning to a controlled point/lightning rod.
Guidance Source	Bessa & Block (2017); Cook (2018, interview); Friesen & Volpé (2012); Howes (2018, interview); Huhnke (2018, interview); Marsollek (2018, interview); McGill & Darr (2014); Rainey (2017, Interview); Searcy (2018, interview); Tudman & Hvisdas (2018, interview); Webb (2016); Webster (2017, interview)

6.2.4 INTAKE CONSISTENCY AND RELIABILITY OF PROPONENT

Rationale	Consistency of feedstock intake is valued by suppliers and contributes to supply chain strength. Consistency of Proponent intake should be equal to, or better than, that of competing markets for feedstock supply of equivalent quality.
Reporting	**Reporting Requirements** Proponent shall demonstrate understanding of: 1. Number of expected intake days, as well as number and duration of expected shutdowns. 2. Ability to continue to intake feedstock during unplanned outages or breakdown. 3. Consistency and reliability of intake versus local competitors.

Guidance	**Guidance for Reporting Requirement 1** Proponent should provide advance notification to suppliers of planned outages or shutdowns. In the case of unplanned shutdown, minimum advance notification should be given to all suppliers and specified in supplier Agreements. In case of unplanned outages, monthly quantities should be prorated accordingly. **Guidance for Reporting Requirement 2** If Proponent's ability to intake feedstock during unexpected outages is limited, outside storage or alternative markets can support supply chain consistency. Availability of "overflow" markets can limit the impact of unexpected outages on suppliers. **Guidance for Reporting Requirement 3** If the large inventory capacities of competitors enable them to be more consistent and reliable consumers of feedstock, then the Proponent is at a competitive disadvantage. If intake consistency/reliability is less than local competitors, then risk of supplier breach increases and inventory capacity should be increased.
Guidance Source	Carollo (2017, interview); De Meyer et al. (2014)

6.3 Risk Factor: Internal Feedstock Yard Operations

6.3.1 RECEIVING YARD EFFICIENCY

Rationale	Efficiency of receiving yard operations directly impacts supply chain strength; yard efficiency is a function of unloading wait times, hours of operation and required transport/unloading equipment. If receiving hours are atypical or inconvenient, or if unloading wait times are long due to congestion in the yard, then suppliers are more likely to breach and supply chain integrity can be compromised.
Reporting	**Reporting Requirements** 1. Proponent yard operations shall be structured in a manner that minimizes yard congestion, and supplier discharge time and cost. 2. Proponent sampling and testing methods shall be consistently applied and based on industry standards, best practices, or be at least consistent with status quo for the region. 3. Discharge of feedstock shall not require specialized equipment by suppliers. **Reporting Recommendations** 1. Proponent should demonstrate that the following elements of yard operations are equal to, or better than, that of major competitors for feedstock: • Receiving hours • Wait times (arrival-discharge-exit) • Sampling and testing • Yard equipment • Protocols for dealing with rejected loads
Guidance	**Guidance for Reporting Requirement 1** Discharge time for suppliers should be less than 1 hour on average. Shorter times are preferable and 20 minutes is ideal (Rob 2017). If wait times are excessive, Proponent-Supplier agreements should compensate supplier for additional wait time. If the facility is not yet built, a computer simulation should be carried out to determine the number of trucks that can be accommodated over a given time period, expected wait times and potential congestion. The IBSAL-MC model can help address receiving yard inefficiencies. This model encapsulates all logistical costs of operations and helps reduce inefficiencies within operations, such as unloading times and costs (Ebadian et al. 2011).

	Guidance for Reporting Requirement 2 See 1.2.6 for sample testing methods **Guidance for Reporting Requirement 3** Yard should enable discharge of most common equipment used for transport. For example, if suppliers traditionally deliver feedstock in open top dry van trailers, then Proponent should not require walking floor trailers. Requiring more expensive transport or unloading equipment can increase delivery costs and decrease supply chain resilience by excluding a portion of potential suppliers. **Guidance for Reporting Recommendation 1** Proponent should provide hours of operation that are coinciding with, or more flexible than, those of competitors. Flexibility of feedstock yard receiving hours can influence the attractiveness of the Proponent to suppliers and strengthen supply chains; this is especially the case in urban areas where traffic can create problems for suppliers.
Guidance Source	De Meyer et al. (2014); Ebadian et al. (2011); Rob (2017, interview)

6.3.2 SAMPLING AND TESTING METHODS IN YARD

Rationale	It is important that sampling and testing methods accurately represent the quality of feedstock delivered by suppliers. Communication of sampling and testing procedures is necessary to ensure that suppliers understand expectations regarding feedstock quality. Suppliers should have a direct line-of-sight between loads delivered and feedback on quality of material. Deliveries of out-of-specification material and deductions for such, if any, should be communicated promptly, and in a manner that enables suppliers to remedy issues.
Reporting	**Reporting Requirements** Sampling and testing methods shall: 1. Be the responsibility of, and be carried out by, the Proponent, not the supplier 2. Be consistently and promptly applied 3. Not unduly impact wait times 4. Be communicated to suppliers 5. Be based on industry standard practices, or be at least consistent with status quo for the region. **Reporting Recommendations** 1. Deductions for out-of-specification material should be consistent with those for alternative markets.
Guidance	**Guidance for Reporting Requirement 1** See Section 1.2.6 for sample testing methods **Guidance for Reporting Requirement 2** Samples should be tested immediately after receipt. Out-of-specification feedstock should be flagged, and issues communicated promptly to suppliers. Undue delay in sample testing may result in incorrect results and controversy with suppliers. **Guidance for Reporting Requirement 4** A robust guideline that includes testing method, testing frequency and data management should be specified in internal feedstock procurement protocols and communicated with suppliers. **Guidance for Reporting Requirement 5** The feedstock quality testing procedures should follow established local practices that are accepted by suppliers.

	Woody Biomass. Resources are available from FPInnovations that outline the established best practices and standards currently in operation across the industry. Quality measurement tools and optimal feedstock specifications are presented by Volpé (2014, 2013c). **Agricultural Residues**. A recommended practice is to sample around 20% of bales on each load, and sample each bale multiple times (Jackson 2017).
Guidance Source	Crummett (2017, interview); Jackson (2017, interview); Rainey (2017, interview); Solomon (2019, interview); Steiner et al. (2012); Webster (2017, interview)

6.3.3 YARD AND EQUIPMENT REDUNDANCY

Rationale	A lack of redundant equipment and infrastructure in the yard increases the impact of equipment breakdown. Major replacement parts should be available on-site to minimize impact.
Reporting	**Reporting Requirements** 1. Redundancy shall be built into yard equipment infrastructure to minimize disruptions from equipment breakdowns. **Reporting Recommendations** 1. The importance of each piece of yard equipment to the flow of feedstock shall be qualified and contingency plans in the event of breakdown should be specified.
Guidance	**Guidance for Reporting Requirement 1** Essential equipment, such as scales and truck tippers, should be given particular focus. **Guidance for Reporting Recommendation 1** Contingency plans should include lists of equipment and spare parts to be held in inventory; lists of nearest suppliers of essential equipment and spare parts that are not held in inventory; pre-arrangements with contractors for repairs and expected timeframes for key repairs to take place.
Guidance Source	Cook (2018, interview); Marsollek (2018, interview)

6.3.4 DIRECT FEED VERSUS INDIRECT FEED

Rationale	If feedstock is unloaded directly into reactor throat (or reclaimers) then control over quality is diminished and risk of quality issues increases. Discharge of feedstock on ground and subsequent loading into reactor feed system enables visual inspections, quality testing and, if necessary, rejection of substandard feedstock.
Reporting	**Reporting Requirements** 1. Feedstock shall be unloaded in designated area to allow for inspection and rejection before being utilized. **Reporting Recommendations** 1. Feedstock of different qualities should be stored in separate designated area and subsequently blended to achieve a more homogenous feed (O'Leary 2017). 2. Hard surface yard pads such as asphalt should be used to avoid contamination of dirt, gravel, clay, or sand with feedstock.
Guidance	**Guidance for Reporting Recommendation 2** Goldstein (1996) presents arguments in favor of composting operations investing in hard surface yard pads. This reasoning is applicable to all biomass pile management.
Guidance Source	Goldstein (1996); O'Leary (2017, interview)

6.3.5 SMART DEVICES IN INVENTORY MANAGEMENT

Rationale	The use of advanced technologies in feedstock yards can lower the risk of quality variances and fire.
Reporting	**Reporting Recommendations** 1. Proponent's inventory yard should incorporate smart devices that reduce risk of quality variances and fire.
Guidance	**Guidance for Reporting Requirement 1** Conveyor belt sensors can identify feedstock of low quality and reject it before it enters facility; dust sensors can prevent explosions; temperature sensors can prevent spontaneous ignition in piles.
Guidance Source	Ebadian (2018, interview); Pecanins (n.d.)

6.4 Risk Factor: Management and Personnel

6.4.1 PERSONNEL EXPERIENCE IN FEEDSTOCK PROCUREMENT AND YARD OPERATIONS

Rationale	Effective management of feedstock supply chains requires experienced professionals. At the present time, there is no accredited program for skills development or certification for biomass feedstock management or procurement. As a result, bio-economy projects may lack access to experienced personnel. Hiring individuals with related but not directly relevant experience is a common risk factor for bio-projects. For example, a Proponent processing agricultural residue into biofuels may hire a corn ethanol procurement expert, despite the fact that issues around corn procurement are substantially different than those around agricultural residue procurement (e.g., harvest practices of suppliers and variance in feedstock quality is of lesser concern for corn). Such discrepancies in knowledge and experience can increase supply chain risk.
Reporting	**Reporting Requirements** 1. Feedstock yard manager shall have relevant yard management experience with feedstock types. 2. Feedstock procurement manager shall have relevant experience with feedstock types.
Guidance	**Guidance for Reporting Requirements 1-2** Local experience is preferred.
Guidance Source	Crummett (2017, interview); Ebadian (2018, interview); Nguyen (2017, interview); Spikes (2017, interview)

6.4.2 DATA MANAGEMENT SYSTEMS AND PROCESSES

Rationale	Data management systems and processes are critical to effectively managing and optimizing biomass operations, and function to mitigate supply chain risk. A robust, centralized feedstock procurement data management system allows for control over feedstock supply at both the plant and corporate levels, and enables the development of strategies and tactics to minimize risks related to feedstock supply.
Reporting	**Reporting Requirements** 1. The use of feedstock procurement software shall be incorporated into the procurement plan. Software shall allow for control over feedstock supply as well as for comprehensive data analysis. 2. Procurement plans shall demonstrate a process by which the feedstock information flows regularly to upper management, preferably through a corporate level feedstock manager.

Guidance	**Guidance for Reporting Requirement 1** Instant access to locations of feedstock, type and date of harvesting, is important to lowering feedstock supply risks. Genera's Supply ASSURE software oversees and coordinates harvesting, aggregation, storage and transportation. A critical part of the Supply ASSURE system is industrial inventory management and control through a sophisticated data collection, monitoring and integrated software system that offers traceability of product. Weather can have significant impacts on the quality and delivery of feedstock that is grown or stored outdoors. Understanding short and long-term weather forecasts enables better management of feedstock suppliers and quality. For example, management can communicate with suppliers to schedule grinding operations during dry days versus rainy. **Guidance for Reporting Requirement 2** Supply risk is minimized when feedstock management forecasts and Key Performance Indicators (KPIs) are set at the corporate level, and are consistently communicated to the plant. Plant level procurement and yard management should communicate feedstock-related risks directly to upper management, and be in a position to acquire necessary resources for adequate feedstock risk management.
Guidance Source	Crummett (2017, interview); O'Leary (2017, interview); Rob (2017, interview); Spikes (2017, interview); Webster (2017, interview)

6.4.3 PERSONNEL SAFETY TRAINING PROTOCOLS

Rationale	Continuous personnel training is necessary to ensure safe and efficient yard operations, and prevent supply disruptions.
Reporting	**Reporting Requirements** 1. Personnel safety training protocols shall be included in the project management plan and should comply with all relevant safety standards and regulations.
Guidance	**Guidance for Reporting Requirement 1** Information on personnel safety protocols can be found at the Occupational Safety and Health Administration (OSHA 2019). Equipment manufacturers typically provide detailed guidance on safe operations of equipment. Many states also have safety standards in place for farm workers. For example, California's Occupational Safety and Health Administration (OSHA) program provides resources and guidance to protect agricultural workers against heat, injury and illnesses from multiple hazards. Recent trends in woody biomass facility accidents are described by Krigstin et al. (2018). The paper provides recommendations for inventory monitoring technology usage to address the incidents of worker safety hazards.
Guidance Source	OSHA (2019); Krigstin et al. (2018); Rainey (2017, interview)

6.4.4 RELATIONSHIPS WITH SUPPLIERS

Rationale	Poor relationships with even a small number of suppliers can turn into a broader reputational problem, making it more difficult to procure feedstock. Such situations increase the risk of lower feedstock quality, decreased availability and inflated prices. Frequent site visits and open lines of communication with suppliers support a robust and resilient supply chain. Suppliers are an important source of feedstock market knowledge. Suppliers can share important information about expected price changes, new market entrants and competitor behaviors. Such information can be crucial in procurement planning. Having a supplier base which regularly shares information with the feedstock procurement team can lower supply chain risk significantly.

Reporting	**Reporting Requirements** 1. Proponent shall demonstrate a plan for fostering positive supplier relationships that includes at minimum: • Frequency of on-site visits • Actions in case of contract breach, out-of-specification feedstock or delivery issues. **Reporting Recommendations** 1. A procurement professional experienced in the local feedstock supply basin with developed relationships with local suppliers is an asset.
Guidance	
Guidance Source	Baylies (2017, interview); Cook (2018, interview); Crummett (2017, interview); Curran (2017, interview); Hladik (2017, interview); Marsollek (2018, interview); Rainey (2017, interview); Rob (2017, interview); Webster (2017, interview)

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Annex 2: Interviews and Comments

Althoff, Kyle	President	Equinox	9/6/2017
Altman, Ira	Dept. Chair, Agribusiness Economics	University of Southern Illinois	5/25/2018
Baylies, Charlie	Fuel Procurement Manager	EWP Renewable Corp.	4/19/2017
Bergtold, Jason	Associate Professor	Kansas State University	5/28/2018
Betts, Nick	Director, Americas	Sustainable Agriculture Initiative Platform	3/27/2019
Bi, Tony	Professor	University of British Columbia	3/29/2019
Bloomfield, Peter	President	Concord Steam Corp.	6/6/2017
Bressler, David	Professor	University of Alberta	3/27/2019
Brown, Jim	President	Onalaska (Karr)	5/23/2017
Carollo, Paolo	VP of Operations	Chemtex International	6/6/2017
Cook, Stacy	President	Koda Energy	4/27/2018
Crummett, Rob	Director of Fuel Procurement	Green Leaf Power	5/9/2017
Curran, Patrick	President	Curran Renewable Energy	7/26/2017
Daly, Christopher	Senior Research Professor	Oregon State University	11/7/2017
Darr, Matthew	Professor	Iowa State University	8/2/2017
Davis, Mike	Fiber Procurement Manager	NOVEC	5/24/2018
Dujmovic, Marin	Feedstock Quality Specialist	Walker Environmental	4/2/2019
Eaton, Laurence	Natural Resource and Environmental Economist	Oak Ridge National Lab	1/19/2018
Ebadian, Mahmood	Biomass Supply Chain Risk Consulting	Principal	4/25/2018
Ericsson, Jerry	CEO	Diacarbon Energy	6/29/2017
Farris, Glenn	Marketing Manager – Biomass	AGCO	10/6/2017
Ferguson, Sandy	VP Corporate Development	Conifex Inc.	11/12/2017
Godecha, Rajdeep	Founder	Zdaly (formerly Analyst for BP)	5/17/2018
Griffel, Mike	Researcher – Agronomy	Idaho National Lab	2/14/2018
Gunn, Geoffrey	Geographer	International Institute for Sustainable Development	3/29/2019
Halbleib, Michael	Professor and Director of PRISM Climate Group	Oregon State University	11/7/2017
Hansen, Jason	Economist, Modeling and Simulation	Idaho National Lab	2/7/2018
Hartley, Damon	Researcher – Biomass Supply Chains	Idaho National Lab	2/21/2018
Hladik, Maurice	Independent Consultant and Author	Independent Consultant and Author	6/9/2017
Howes, Pat	Bioenergy Knowledge Leader	Ricardo Energy & Environment	2/7/2018
Huhnke, Ray	Director, Biobased Products and Energy Center	Oklahoma State University	12/8/2017
Hvisdas, James	Vice-President	Sweetwater Energy	5/16/2018
Jackson, Sam	VP, Business Development	Genera Energy	9/26/2017
Jenkins, Darrell	CEO	Phoenix Power Group	7/18/2017
Kaffka, Stephen	Director, California Biomass Collaborative	University of California – Davis	12/18/2017
Karlen, Doug	Soil Scientist	USDA-ARS	11/17/2017

Keller, Alan	Biomass Logistics	POET	9/5/2017
Krigstin, Sally	Assistant Professor	University of Toronto	6/22/2017
Layzell, David	Professor and Director, Canadian Energy Systems Analysis Research	University of Calgary	3/29/2019
Leary, Michael	Asset Manager	Bridgewater Power	8/17/2017
Marsollek, Mike	VP Supply Chain	Koda Energy	4/27/2018
Mills, Lucy	Director, Business Processes and Strategy Deployment	Enginuity Worldwide	5/12/2017
Mitchell, Rob	Research Agronomist	USDA-ARS	12/12/2017
Morris, Dave	Research Scientist	Ontario Ministry of Natural Resources and Forestry	3/29/2019
Muth, David	AgSolver Manager	EFC Systems	11/7/2017
Negri, Cristina	Principal Agronomist	Argonne National Lab	2/14/2018
Owens, Vance	Regional Director	South Dakota State University	11/13/2017
Parrish, Barry	Fiber Procurement and Sustainability	Georgia Biomass	1/17/2018
Passmore, Jeff	President	Passmore Group	6/6/2017
Pieper, John	Agronomy Manager	Pioneer (Dupont)	9/8/2017
Rainey, John	Senior Energy Contracts Originator	Novec Energy Production	6/6/2017
Riedy, Mark	Partner	Kilpatrick Townsend	4/3/2019
Robb, Tom	Consultant	Formerly Abengoa	7/28/2017
Rodstrom, Andrew	Crop Protection & Certification Manager	GreenWood Resources	5/29/2018
Rummer, Bob	Director of Research Development	University of Kansas	5/25/2018
Searcy, Steven	Senior Professor & Department Head	Texas A&M University	1/17/2018
Smith, Don	Principal	Nawitka Inc.	3/27/2019
Smith, Tat	Professor	University of Toronto	1/31/2018
Smith, William	Consultant	Idaho National Lab	7/18/2017
Sokhansanj, Shahab	Professor	University of British Columbia	5/24/2018
Spikes, Kirk	Consultant	Formerly Abengoa	7/18/2017
Stanners, Scott	Executive Director	BC Bioenergy	3/28/2019
Stuthridge, Alex	Executive Director	BioInnovative Renewables Network	3/29/2019
Swan, David	CEO	ecoOptions Energy Cooperative	3/27/2019
Tan, Eric	Biorefinery and Sustainability Analysis	NREL	5/23/2018
Ter-Mikaelian, Michael	Research Scientist	Ontario Ministry of Natural Resources and Forestry	3/27/2019
Tudman, Scott	CTO	Sweetwater Energy	5/16/2018
Tumuluru, Jaya	Research Scientist	Idaho National Lab	3/1/2018
Venema, Henry	Former Director of Planning, Prairie Climate Centre	International Institute for Sustainable Development	2/11/2018
Vroegh, Martin	Senior Director, Greenhouse Gas Reduction Technologies	Ontario Centers of Excellence	3/29/2019
Wang, Michael	Senior Scientist – Energy Systems	Argonne National Lab	1/15/2018
Webster, Keith	Ag Specialist III	Iowa State University	8/2/2017
Wever, Paul	Owner	Chip Energy	5/30/2017
Wiberg, Chris	Lab Director	Biomass Energy Lab	11/17/2017

Annex 3: Risk Ratings Review Committee Members

Michael Ekhart
Managing Director, Global Head of Environmental Finance and Sustainability
CITIBANK, CITIGROUP

Michael is a Managing Director and Global Head of Environmental Finance in the Corporate and Investment Banking division of Citigroup in New York City. He leads Citi's work in sustainable finance, including originating the Green Bond Principles. Previously, he was the founding President of the American Council On Renewable Energy (ACORE), a Washington DC-based non-profit organization, where he emerged as a national and global leader in the renewable energy field. Earlier, he developed financing for solar energy under the SolarBank Initiative in Europe, South Africa, and India; was Chairman & CEO of United Power Systems, Inc.; Vice President of Areté Ventures, Inc.; a strategic planner of General Electric Company's power systems sector; and a Principal with the energy practice of Booz, Allen & Hamilton. He has been key in developing green bonds.

He has received numerous awards and recognitions, including Renewable Energy Man of the Year of India in 1998, the Skoll Award for Social Entrepreneurship in 2008, the Good Deal for All Award in 2009, the ISES Hermann Scheer Global Leadership Award in 2013, and Biofuels Financier of the Year in 2014. He received a degree in Electrical Engineering from Purdue University and an MBA from Harvard Business School, and served in the US Navy Submarine Service.

Peter Johnson
Director, Environmental and Social Risk and Opportunity
SCOTIABANK

Scotiabank is the third largest bank in Canada with more than C$850 billion in assets.

As Director of Environmental and Social Risk and Opportunity for Scotiabank, Peter is focused on making companies more successful through the integration of environmental risks and opportunities into business practices, products, and brands. A recognized pioneer and leader in shaping corporate sustainability, Peter has worked across many sectors developing and implementing business-centric programs around sustainability, climate change, risk management, CSR, stakeholder and employee engagement, metrics and reporting.

Currently, Peter works on Environmental and Social Risk within Global Risk Management at Scotiabank's headquarters in Toronto. In his role Peter is responsible for identifying and managing current and emerging environmental, social and sustainability risks and opportunities across Scotiabank's 55 country operational footprint. Peter maintains an extensive network of environmental, business, ENGO and sustainability colleagues across Canada and around the world. Peter was the first certified sustainable forest management (SFM) auditor in North America, and holds a Bachelor of Science in Forestry from the University of Toronto and a Master of Science in Forestry from Lakehead University.

Justin Goldstein

Vice President

GOLDMAN SACHS

Goldman Sachs is one of the largest investment banking, securities and investment enterprises in the world, ranked 70th on the Fortune 500 list of the largest United States corporations by total revenue. Since 2012, It has deployed more than $71 billion to clean and renewable energy.

As Vice President in the Goldman Sachs Alternative Energy Investing Group, Justin Goldstein leads investment into renewables deploying capital in the alternative energy sector through a broad range of financing solutions, including private growth equity debt, term loans and tax equity.

In 2015, as part of its Environmental Policy Framework, Goldman Sachs expanded its existing target to $150 billion in capital deployment for the clean energy sector by 2025, reinforcing a long-term commitment to and conviction in the clean energy sector. This builds on its $40 billion target established in 2012. The target is focused on the clean technology and renewable energy sector, and on commercial transactions and includes financing and co-investments for biomass, and advanced biofuels.

Alvaro Andrada

Business Development Manager, Special Enterprise Risks

MUNICH REINSURANCE COMPANY

Munich Reinsurance Company (Munich Re) is the world's 19th-largest financial services company by revenue ($88 billion) with 42,000 employees and over $54 billion of premiums written in 2017. Munich Reinsurance America is a subsidiary of MunichRe with an A+ financial strength rating from A.M. Best Company.

MunichRe Green Tech Solutions has recently developed Bioenergy Plant Performance Insurance to protect the balance sheet and balance cash flows for bioenergy plants and projects. The instrument improves bankability and access to capital, stabilises revenue stream and enables more cost-efficient financing.

Dani Lipkin

Innovation Sector Head, Capital Formation

TORONTO STOCK EXCHANGE AND TSX VENTURE EXCHANGE

The TSX is the 9th largest exchange in the world by market capitalization. The TSX Venture Exchange is a public venture capital marketplace for emerging companies a combined market capitalization of >$60 billion as of 2010.

Dani Lipkin carries the role of Innovation Sector Head for both Toronto Stock Exchange (TSX) and TSX Venture Exchange (TSXV). In this capacity, he is responsible for working with private companies and their shareholders as they explore and consider the option of raising equity capital in Canada. Prior to this role, Dani was the Head of Business Development for Exchange Traded Funds (ETFs) and Investment Funds on TSX. He had also worked with the listings group for TSX, where he helped assist companies in going public.

Vivian Kan

Director, Cleantech Practice

BUSINESS DEVELOPMENT BANK OF CANADA (BDC)

The Business Development Bank of Canada (BDC) is a federal Crown corporation wholly owned by the Government of Canada with assets of $25.3 billion and 2,200 employees at more than 118 business centres across Canada. Its mandate is to help create and develop Canadian businesses through financing, growth and transition capital, venture capital and advisory services, with a focus on small and medium-sized enterprises.

Vivian Kan is Director, Cleantech Practice, at BDC. Vivian has over 15 years of experience in business development, structuring, risk analysis, and commercial and corporate finance. She has helped some of Canada's top exporters and emerging global entrepreneurs in sectors ranging from cleantech, oil and gas, mining, transportation, infrastructure, light manufacturing, life sciences, aerospace, forestry pulp and paper, and consumer products.

Prior to joining BDC in 2017, Vivian spent over 14 years at as Financing Manager at Export Development Canada (EDC), Canada's export credit agency, where she analyzed lending opportunities with start-ups as well as small and mid-size companies with high growth potential. Vivian also worked as an underwriter at EDC, where she developed risk mandates to provide bonding solutions for Canadian cleantech ventures.

Francois Ioos

Vice President, Biofuels Division, Total Raffinage Chimie SA

Total S.A.

Total is one of the seven "Supermajor" oil companies in the world and a large-scale chemical manufacturer. Its climate strategy is based on three pillars: improving the carbon intensity of its energy mix, energy efficiency and developing renewable energies. Total is a member of the Oil and Gas Climate Initiative (OGCI), a CEO-led initiative made up of ten oil and gas companies with a 1-billion-dollar climate investment fund to invest in cutting the climate change impact of fossil fuels. Total has also launched the BioTfueL project to transform lignocellulosic biomass (straw, forest waste, dedicated energy crops) into biofuel via thermochemical conversion.

Francois has worked with Total for over 20 years in both strategy and management roles across North America, Europe and Africa. Since 2018 he has served as the VP of Total's Biofuels Division, spearheading the adoption and incorporation of biodiesel into the global transportation industry.

Andrew Murfin

General Manager, Advanced Biofuels Division

ROYAL DUTCH SHELL

Royal Dutch Shell (Shell) is an international energy company with expertise in the exploration, production, refining and marketing of oil and natural gas, and the manufacturing and marketing of chemicals with annual revenues of $388 billion. Shell was one of the first energy companies to invest in making advanced biofuels from alternative feedstocks and continues to invest in new ways to produce biofuels from sustainable feedstocks. Shell is s accelerating its move into alternative energy, with plans to spend up to $1 billion per year on its New Energies division by 2020. It is currently one of the largest blenders and distributers of biofuels in the world.

Andrew Murfin, is General Manager at Shell's Advanced Biofuels division. Mr. Murfin joined Alternative Energies in 2009 and was appointed GM Advanced Biofuels at the beginning of 2013. In his current role, he has global accountability for the delivery of an advanced biofuels manufacturing business. He has over 25 years' commercial, project and technology implementation experience.

Mr. Murfin has worked in the renewable energy field since 2001 and joined Shell in 2003. Prior to his current role, Mr. Murfin was in Canada, developing a proposed project to deliver a cellulosic ethanol facility in conjunction with government funding and technology providers. Previously, he was project director of the now operational $3 billion London Array offshore wind project in the UK. He spent much of his early career in a range of commercial, mergers and acquisitions, new business development and trading roles in the UK utility industry. Mr. Murfin has a first degree in Electro Mechanical Engineering, is a Fellow of the Energy Institute and a Chartered Engineer.

Trystan Glynn-Morris

Project Finance Manager

EXPORT DEVELOPMENT CANADA (EDC)

Export Development Canada (EDC) provides insurance, financial services and business solutions to Canadian exporters and investors, and their international buyers. Since it's inception, EDC has facilitated more than $1.5 Trillion in exports and foreign investment by Canadian companies. Using EDC financial products and services, businesses' export sales and investments approximated $105 Billion. EDC also estimates that it has helped generate $67 Billion for Canada's GDP, and helps to sustain 488,637 jobs.

Trystan has over 5 years of experience in project delivery in the energy, mining and infrastructure sectors, as well as 5 years of experience in project finance with EDC. He holds an MBA from the University of Ottawa where he obtained a Focus in Finance and Sustainability. He also holds an MSc from Queen's University in Geological Engineering, Mineral and Energy Exploration.

Gildas Poissonnier

Manager, Sustainability and Responsible Finance

DESJARDINS

Desjardins is a Canadian banking cooperative and the 6th largest financial co-op in the world with over C$270 billion in assets.

Gildas heads Desjardins sustainability and responsible finance team, leading the company towards integrated environmental, social and governance ratings criteria for all decision making and operations. He also supports the bank's development of responsible finance products that align with corporate climate change, clean energy and socio-economic development goals that focus on its clients and members.

Anne-Catherine Mathiot

Managing Director, Head of Downstream & Marketing

Vanessa Chrifi Alaoui

Vice President, Structured and Trade Commodity Finance

BNP PARIBAS

BNP Paribas is currently the world's 8th largest bank by total assets and has key positions in Domestic Markets & International Finances and Corporate & Institutional Banking. By developing several green initiatives and international partnerships BNP Paribas has become a leading player in sustainable finance with several cutting-edge financial solutions, such as sustainable loan platforms.

In 2019, BNP Paribas was named "Best bank in the world for its Corporate Responsibility" by Euromoney, resulting from efforts to build a new inclusive and sustainable bank model. The Group's commitment to sustainable finance is evident with green bonds outstanding of approximately EUR 900 million: the highest in the world. BNP Paribas plans to support clients in energy transition for a low-carbon economy by investing EUR 15 billion in renewable energy by 2020.

As Managing Director of the Energy Downstream and Marketing team at BNP Paribas, Anne-Catherine Mathiot structures and organizes complex transactions in the downstream energy, and agricultural natural resources industry. With over 25 years in the energy and commodity sector in both North America and Europe, Anne-Catherine has extensive experience working with energy merchants, logistics distributors, traders and marketers, including private, public and sponsor backed corporates.

Vanessa Chrifi Alaoui is the Vice President at BNP Paribas, specializing in structured and trade commodity finance.

Ali Naqvi

Portfolio Manager, Real Assets Strategy

CANADA PENSION PLAN INVESTMENT BOARD

The CPP Investment Board manages over $368 billion in investment assets for the Canada Pension Plan on behalf of 20 million Canadians. CPPIB is one of the world's largest sovereign wealth funds and one of the world's largest investors in private equity, having invested over US$28.1 billion between 2010 and 2014 alone.

Ali Naqvi has 15 Years of experience in real assets and is currently a member of The Real Assets Strategy Group at Canada Pension Plan Investment Board (CPPIB). He joined CPPIB in 2014 in the Total Portfolio Management Group, focused on infrastructure. Prior to joining CPPIB, Naqvi was responsible for the Real Assets Portfolio of Ontario Power Generation's (OPG) Pension Plan. Before that, he was with Macquarie in their infrastructure, private equity and investment banking groups in Toronto and London.

John M. May
Managing Director, Renewable Energy Finance
HAMILTON CLARK

Hamilton Clark is a leading US investment bank, focusing on biofuels, biomass, biochemical and bio-products.

John May leads the Renewables practice at Hamilton Clark and is recognized as one of the top renewable energy bankers in the US. He has been involved in the financing of over $11 billion in loan and par values for over 100 clients in his 25-year banking career.

John is credited with having pioneered the use of bonds as a form of project finance debt in the renewables market. In 2005, John was responsible for developing one of the first tax-exempt bond structures sold to major U.S. institutional investors to fund ethanol projects. He was the first banker to use a State guarantee of debt for a biofuel financing. In 2006, he introduced the use of bonds as a complement to syndicated bank debt in large biofuels financings. In 2008, he was placement agent for bonds used to finance the first U.S. ethanol plant with an off-take agreement from a major international oil company. In 2010, he created the bond finance structure adopted by the USDA in its Bio-Refinery Loan Guarantee Program; this resulted in the Agency's adoption of a new Interim Final Rule for the program in 2011. In 2012, John led the investment banking team that closed the first project financing for a biochemical company in U.S. history, for Myriant Corporation. The deal was awarded "Deal of the Year" by Biofuels Digest Magazine for 2012.

Previously, John was Co-Head of Stern Brothers Renewable Energy Practice, which he founded in 2003 and developed into one of the most recognized brands in the financing of biofuels in the U.S. In 2012, John was voted one of the "Top 100 People in Bioenergy 2012". In 2013, John was named the 50th most influential person in the world in Bioenergy by Biofuels Digest. John has provided counsel on financing options and the credit markets to the USDA, the Staff of the U.S. House Agriculture Committee, the U.S. Department of Energy/NREL, and the United States Congress Joint Committee on Taxation. In 2011, John was elected to the Advisory Board of the Rockefeller Brothers Fund's Climate Prosperity Partnership. John has been serving on the Power Generation & Infrastructure Advisory Committee of the American Council on Renewable Energy (ACORE) since 2013.

Greg Aguilar
Vice President, Renewable Energy Finance
RABOBANK

In 2018 Sustainalytics ranked Rabobank as the number 1 bank in the world in terms of global sustainability, referencing the bank's application of ESG data in risk assessments and lending operations as a major contributing factor to the top ranking. Rabobank is also the leading green bank in the Netherlands, with over US$650 billion in assets. As of 2016, 99% of its US$3.9 billion energy sector investments were in renewable energy.

Greg is responsible for supporting the renewable energy financing needs of Rabobank's clients, as well as developing strategic partnerships with renewable energy developers and manufacturers in alignment with Rabobank's global sustainability mission. Rabobank's Project Finance team has a global presence and a strong focus on advising, structuring, arranging and underwriting project finance transactions with a focus on the renewable energy and infrastructure sector. Greg has previous experience with Boeing, and holds an MBA from Pepperdine University.

Emily Chew

Managing Director, Global Head of ESG

MANULIFE ASSET MANAGEMENT

Manulife Asset Management is the global asset management arm of Manulife, with assets under management of approximately C$435 billion. Emily leads Manulife Asset Management's team of dedicated ESG research and integration analysts to advance the firm's ESG agenda. In her role, she oversees the team of ESG analysts that work with portfolio management teams on progressing ESG integration processes and conducting ESG engagement with investee companies; works with Manulife Asset Management's sales and product teams on ESG strategy and marketing; and represents Manulife Asset Management on various industry groups and collaborative initiatives.

Before joining Manulife Asset Management, Emily was Head of ESG Research for Asia-Pacific at MSCI Inc., where she led a team of nine ESG analysts across the region, commencing her role in Beijing and later continuing in Hong Kong. Her team had oversight into research quality and issue identification for approximately 1,200 stocks, and under her leadership produced original research on the relevance of ESG to Asian and emerging markets, with a particular emphasis on China. Prior to that, she was a capital markets lawyer with Baker & McKenzie in Melbourne, Australia, with a focus on funds management, capital raisings, and REITs.

Emily holds an MBA from the University of Oxford, and Bachelor of Laws and Bachelor of Arts from the University of Melbourne. She is a member of the United Nations-sponsored Principles for Responsible Investment's Listed Equities Integration Subcommittee, and the Steering Committee for the Climate Action 100+ global collaborative investor engagement initiative. She previously served as chair of the Asian Investor Group on Climate Change's Member Working Group from 2016 to 2018.

Scott Jacobs

Co-Founder & Chief Executive Officer

GENERATE CAPITAL

Generate Capital is a leading capital partner for technology manufacturers, project developers, and system integrators in the renewable energy, technology, finance and sustainability sectors with decades of collective experience financing billions of dollars of sustainable infrastructure. Generate is an investment and operating platform that builds, owns, operates, acquires and finances innovative resource infrastructure. Since its launch in 2014, the firm has built more than $500 million of sustainable infrastructure across the power, transportation, and water and waste sectors.

Scott is co-founder and CEO, leading sustainable infrastructure investment and investing in and operating distributed generation, energy efficiency, waste transformation, sustainable agriculture, and water projects.

Scott co-founded McKinsey's Global CleanTech practice in 2007, serving leading global institutions in energy, technology, policy and finance, as well as many of the fastest-growing emerging innovators. Prior to McKinsey, he spent 14+ years starting and growing companies -- sourcing and structuring financings, securing key channels and customers, attracting talent, forging initial partnerships, examining strategic options, and executing growth plans.

Tim Marsters

Business Development and Principal Investments

CENTRICA

Centrica plc (LSE:CNA) is the largest supplier of gas to domestic customers in the United Kingdom, one of the largest suppliers of electricity (operating under the trading names Scottish Gas in Scotland and British Gas in England and Wales) and one of the world's leading energy and services companies. It is an international energy and services company that supplies energy and services to over 25 million customer accounts mainly in the UK, Ireland and North America supported by 15,000 engineers and technicians. Centrica owns Bord Gáis Energy in Ireland as well a fleet of flexible power facilities in the UK.

Tim has over 20 years' experience in the commodity and energy markets and is a driver of Centrica's investment in the renewables space. He has a track record in originating and executing equity, financing and derivatives transactions in the private equity, banking and utility sectors.

Mittal Monani

Senior Trader

DIRECT ENERGY

Direct Energy is one of North America's largest energy and energy-related services providers with nearly 5 million residential and commercial customer relationships. A subsidiary of Centrica plc, Direct Energy operates in 46 U.S. states plus the District of Columbia and 10 provinces in Canada.

Mittal Monani is Senior Trader for North American Emissions with Direct Energy based in Calgary AB. Direct Energy is a leading North American energy retailer supplying electricity and natural gas to over 4 million residential, and 250,000 business customers including over 70% of the Fortune 100. Mittal is responsible for trading and origination in RNG, RIN, LCFS, carbon and REC markets in the US and Canada.

Previously, Mittal ran the US Carbon portfolio for Capital Power (TSE:CPX) where he grew the business to become a leader in the California and North-Eastern US (RGGI) carbon markets. Mittal started his career in the energy industry at BP Canada, and acquired extensive trading and analytical background working in North American coal, natural gas, power, and carbon markets at leading energy merchants.

Dr. Mark Summers

Executive Director of Technology and Innovation

EMISSIONS REDUCTION ALBERTA

Mark Summers is the Executive Director of Technology and Innovation for ERA. In this role, he leads ERA's technology evaluation process and team of project managers. Mark's background includes technology investment program and portfolio management, renewable energy technology, and climate change policy. Prior to joining ERA, he was Director of Renewable Energy at Alberta Innovates. He has also served as a Climate Change Engineer in the Climate Change Secretariat for the Government of Alberta, and a researcher at the University of Alberta. Mark graduated from the University of Alberta with a BSc in Engineering Physics and a PhD in nanostructured engineering.

ERA has invested more than $572,000,000 in 164 bio-economy projects to date. ERA projects add more than $2.0 billion to Alberta's GDP, $2.7 billion to the nation as a whole, supported an average of 1,500 jobs annually in Alberta from 2011 to 2023, and 42,7000,000 tons of CO_2 emissions avoided by 2030.

Don G. Roberts
CEO
NAWITKA CAPITAL ADVISORS

Don Roberts is the chief executive officer of Nawitka Capital Advisors Ltd, a firm that provides advice on strategic direction and raises capital for companies in the renewable energy, clean technology, and forest products industries. In 2012, Corporate Knights named Mr. Roberts the individual in the financial services sector who most contributed to sustainable development in Canada. Institutional investors surveyed by Brendon Woods and/or Greenwich Associates ranked Roberts Canada's best analysts for the paper and forest products sector seven times between 1997 and 2008, and in 2006, Forbes Magazine named him one of the best brokerage analysts in North America.

Prior to Nawitka, Mr. Roberts was a vice-chair of wholesale banking and a managing director with CIBC World Markets Inc. In this capacity, he founded and led CIBC's cross-functional Renewable Energy & Clean Technology Team, whose mandate was to establish CIBC as the dominant investment and commercial bank serving Canada's renewable energy and clean technology sector. The team achieved this goal in 2009. While at CIBC, Mr. Roberts also provided senior coverage for companies in the global forest products industry.

Mr. Roberts is known for advising ministers and premiers in Canada and internationally on financing and strategic growth in the resource sectors. Early in his career, he spent ten years as a senior economist and a chief economist in the Department of Forestry, Government of Canada.

In addition to his work with Nawitka Ltd., Mr. Roberts is an adjunct professor in the Department of Forest Resource Management at the University of British Columbia and a member of the boards of directors/advisors of Kruger Inc. (Montreal), Endurance Wind Power (Vancouver), Ensyn Technologies Inc. (Ottawa), and the Rights and Resources Institute (Washington DC). In addition, he advises a range of government, industry, and NGO groups.

Mr. Roberts holds a master's degree in forestry economics from the University of California at Berkeley and an MBA in international finance and economics from the University of Chicago. He is a certified board director with the Institute of Corporate Directors.

Phil Cull
CEO
NATUREBANK ASSET MANAGEMENT INC

Phil's broad-based experience in financial markets and scientific training drew him to the carbon market where finance, technology and social development intersected. Prior to that Phil spent seven years in London working with American Express Bank, HSBC, Société Générale and Goldman Sachs. Phil was an Executive Director at Goldman Sachs in their Agency Equity Lending business, heading up the trading desk in London. Phil was also involved in the broader equity finance market and sat on the Corporate Governance committee for the global industry association ISLA.

Phil has a BSc in Applied Geology from the University of Hertfordshire. He then spent a year working as a research student at St. Andrews investigating high temperature ceramics for fuel cell applications. Influenced by his academic expertise, Phil was drawn to a career in climate change, in particular, the interaction between science and finance. Phil later earned his MSc in Climate Change and Risk Management from the University of Exeter in the UK. His postgraduate research focused on the European emissions trading scheme and its relationship to European power and energy prices.

Peter Zaltz

Executive Vice President, Co-Chief Investment Officer & Head of Fixed Income

GLUSKIN SHEFF

Peter is Executive Vice-President, Co-Chief Investment Officer & Head of Fixed Income, and also acts as a Portfolio Manager focusing on fixed income and credit alternative strategies. He received a Bachelor of Business degree, majoring in Finance, from the University of Texas at Austin. He has also earned his Chartered Financial Analyst (CFA) designation. Peter has over 25 years of experience in fixed income, high yield and investment grade credit trading, as well as global equities. Prior to joining Gluskin Sheff in 2014, Peter served as Managing Director & Chief Investment Officer of Blair Franklin.

Peter also has experience being involved in the management of a diverse range of investment funds at Altamira Management Limited (later Natcan Investment Management), and has held senior positions with Scotia Capital Markets.

Richard Nordin

Managing Director

CHATSWORTH SECURITIES

Chatsworth Securities LLC is an investment banking firm participated as an underwriter in several hundred equity public offerings, and raised nearly $3 billion for traditional and alternative money managers. In addition, we have been an underwriter in municipal bond underwritings and our bond trading team actively trades a variety of issues.

Richard Nordin, Managing Director, has over 20 years experience in private equity capital markets, with extensive experience in the emerging markets of Russia and Eastern Europe. At Chatsworth, his focus is raising capital for Alternative Asset Managers in the clean-tech, and renewables spaces. His previous positions include Managing Director, Central and Eastern Europe at the Carlton Group, where he sourced debt and equity capital for real estate and energy projects. Previously, Mr. Nordin managed a private equity fund with investments in Moscow, St. Petersburg, Kiev, and Almaty, including large-scale infrastructure and telecommunications projects. Mr. Nordin is a CFA Charterholder, and received B.A. and M.A. degrees from Harvard University.

Chris Tindal

Assistant Director and Business Team Lead

CAAFI

The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants and government agencies leading the development and deployment of alternative jet fuels for commercial aviation. Alternative jet fuels offer equivalent safety and favorable costs compared with petroleum-based jet fuels, while also offering environmental improvement and energy supply security for aviation.

Chris Tindal is the Assistant Director of CAAFI where he helps to manage the coalition of stakeholders and provides leadership and strategic guidance to CAAFI's Work Teams, Federal government interagency initiatives, State and Regional programs, and International initiatives. As a veteran of the US Navy, Chris lead the USDA/DOE/DON Alternative Fuels Initiative which develops programs to launch the advanced biofuels industry. Chris also leads the Great Green Fleet effort and is striving to have 50% of the Department of Navy's energy originate from alternative sources.

Due to his extensive work and effort in the alternative fuels area, Chris has been consistently recognized by The Biofuels Digest as being among the Top 100 People in the Advanced Bioeconomy.

Chandra Ramadurai
CEO
EFFICIENCY CAPITAL

Chandra is the CEO of Efficiency Capital, a company that invests in energy efficiency projects across North America. Chandra brings over two decades of experience in general management, investment management, strategy and across industries and geographies including Canada, the US, the Middle East, India, and Europe. He has held CEO / CXO level positions in the various businesses of Suzlon (UK and India) and HCC groups, managing both large-cap and small-cap businesses. Prior to that, he held management roles at Cemex (US and Germany), Standard Chartered Bank (Dubai), MashreqBank, and PricewaterhouseCoopers (India).

Chandra holds an MBA from Duke University. He is also a qualified Chartered Accountant from the Institute of Chartered Accountants of India.

Jeff Manternach

Co-Founder & Chief Financial Officer

RED ROCK BIOFUELS

In 2018, Red Rock Biofuels broke ground on the $320 million renewable fuels facility, a step forward towards taking woody biomass waste and converting it to an estimated 15 million gallons of jet fuel. RRB's technology platform converts woody biomass to low carbon jet, diesel, and naphtha fuels. To meet high demand for low-carbon renewable fuels, RRB is building a global portfolio of biorefineries to convert waste woody biomass into renewable jet and diesel fuels.

Jeff is a co-founder and CFO of Red Rock Biofuels LLC (RRB), where he leads project development, finance, accounting and other corporate functions. Jeff has been in the renewable fuels industry since 2003, and prior to RRB, he led debt capital raises of $400+ million, including a $325 million project finance deal.

Ryan Laverty
Manager, Power and Environmental Origination
TRANSCANADA

TransCanada Corporation is a major North American energy company, based in Calgary, Alberta, that develops and operates energy infrastructure in North America. The company operates three core businesses: Natural Gas Pipelines, Liquids Pipelines and Energy. Ryan has a background in both economics and journalism, and has worked with TransCanada for more than 10 years in various managerial roles. He has an interest in accelerating development of RNG to move through the pipeline infrastructure. Ryan holds an MBA from the University of Calgary.

Ted Todoschuk

Principal Researcher

ARCELORMITTAL DOFASCO

ArcelorMittal is the world's leading steel and mining company with 210,000 employees in 60 countries and looks to flagship sites like ArcelorMittal Dofasco to develop new low emissions technology and products such as biochar that fundamentally change the global steel business. ArcelorMittal Dofasco is Hamilton, Ontario largest private sector employer with approximately 5,000 employees manufacturing 4.5 million net tons of high-quality steel annually.

Ted Todoschuk leads the AMD research and development into biocoal and low carbon alternatives with expertise in iron ore pellet, iron ore pellet reduction, coal and cokemaking.

Larry Richardson

Chief Executive Officer

REENERGY

ReEnergy Holdings LLC, a portfolio company of Riverstone Holdings LLC, owns and operates renewable energy facilities that use forest-derived woody biomass and other wood waste. It also owns facilities that recycle woody biomass from construction and demolition material. ReEnergy operates in four states, employs approximately 300 people and owns and operates six energy production facilities with the combined capacity to generate 245 megawatts of renewable energy.

Larry Richardson is a founder of ReEnergy, sits on ReEnergy's Board of Directors, and is a member of the Company's Executive Committee. He was formerly President and Chief Operating Officer of EAC Operations, Inc., a company that owned and operated waste-to-energy facilities and related businesses for the collection, processing and transportation of solid waste and recyclable materials. Before working at EAC, he held management, project development and technical positions at companies including ABB/Combustion Engineering, Halliburton/Brown & Root and HDR Engineering. Larry is a licensed professional engineer.

Rina Singh

Executive Vice-President, Policy

ALTERNATIVE FUELS & CHEMICALS COALITION (AFCC)

The Alternative Fuels & Chemicals Coalition advocates on behalf of federal policies and federal agency appropriations that stimulate innovations in sustainable aviation fuels, support research and development, fund scale up and commercialization, streamline regulatory requirements, speed deployment, and facilitate industry adoption of new technologies and processes that offer significant improvements in operating costs and efficiency and reduce environmental impacts. Rina currently sits on the International board of directors of the international standards organization ASTM.

Prior to her leadership role at AFCC, Rina was the Managing Director for the Industrial and Environmental Section at the Biotechnology Innovation Organization (BIO), the world's largest trade association representing biotechnology companies, academic institutions, state biotechnology centers and related organizations across the US and more than 35 other nations.

Prior to BIO, Rina worked in general management positions in renewable chemicals and bioproducts business development for Ashland Inc. Previously Rina was at The Dow Chemical Company, where she was a senior research chemist in the engineering thermoplastics group.

Mark Riedy

Partner

KILPATRICK TOWNSEND & STOCKTON LLP

Kilpatrick Townsend is a leading global law firm with significant experience in renewable energy project development. They are an industry leader in corporate sustainability with a company-wide commitment to six positive impact pillars of: community leadership, diversity & inclusion, philanthropy, pro bono work, sustainability, and volunteerism. KT has received a score of 100% on Human Right's Campaign's Corporate Equality Index.

Mark Riedy has over 35 years of experience representing clients in both domestic and international matters, with a focus on renewable energy and infrastructure project development and financing. He has been involved with energy development projects in more than 50 countries and continues to represent clean technology, environmental and infrastructure clients around the world.

Bill Crump

Director, Renewable Energy and Chemicals / Emerging Technologies / Oil and Gas

LEIDOS ENGINEERING LLC

Leidos, formerly known as Science Applications International Corporation (SAIC) has 32,000 employees and US$10.19 billion in annual revenue. Bill Crump is Director, Independent Engineering Practice with over 30 years of engineering and independent engineering experience for oil, gas, and chemicals projects around the world, and renewable energy projects. He has managed and participated in evaluations of alternative energy and chemicals, oil and gas, and chemical technologies for developers, government agencies, and investors, and specializes in understanding and mitigating the risks associated with the design and scale-up of pilot plant and demonstration plant equipment and systems in support of commercial plant development.

Bill Crump develops independent engineering reports for developers in support of their USDA loan guarantee applications under the 9003 Program for Biorefinery, Renewable Chemical, and Bio-based Product Manufacturing Technologies and the Business and Industry Program. He has assisted the United States Department of Energy Office (DOE) of Energy Efficiency and Renewable Energy (EERE) Bioenergy Technologies office (BETO) as its independent engineer for the integrated commercial lignocellulosic biorefinery grants awarded under Section 932 and demonstration plants under Section 942 of the Energy Policy Act of 2005 and for pilot plants under the American Recovery and Reinvestment Act of 2009. He has assisted the DOE with its Project Peer reviews as a reviewer for the 2013, 2015, 2017 reviews and led the Steering Committee in 2019; participated in BETO project merit reviews; served on the DOE task team investigating issues with biomass handling; and currently serves on the Advisory Board to the DOE and the U.S. National Laboratories on biomass handling and conversion (the Feedstock Conversion and Interface Consortium) and assists the USDA on the evaluation of new technology projects.

Dr. Arthur Ragauskas

Governor's Chair for Biorefining and Fulbright Chair in Alternative Energy

UT- OAK RIDGE NATIONAL LABORATORY

Dr. Ragauskas held the first Fulbright Chair in Alternative Energy and is a Fellow of American Association for the Advancement of Science, the International Academy of Wood Science and TAPPI. He assumed a Governor's Chair for Biorefining based at University of Tennessee Department of Chemical and Biomolecular Engineering, with an appointment in the UT Institute of Agriculture's Department of Forestry, Wildlife, and Fisheries and serves in the US Energy and Environmental Sciences Directorate, Biosciences Division, at ORNL.

His program has been sponsored by NSF, DARPA, DOD, USDA, DOE and is aimed at exploiting innovative sustainable bioresources and renewable biopolymers for biofuels, biopower, and bio-based materials and chemicals. His Fulbright sponsored activities at Chalmers University of Technology, Sweden were focused on the forest biorefinery and new biofuel conversion technologies for lignocellulosics. He is the recipient of TAPPI Gunnar Nicholson Gold Medal Award (2014) ACS Award for Affordable Green Chemistry (2014) ORNL Visiting Fellow (2013) Elected American Association for the Advancement of Science Fellow (2012) Elected to Academy Board of International Academy of Wood Science (2012) Fulbright Distinguished Chair in Alternative Energy (2008-2009), and Nominated to National Commission on Energy Policy (2008).

Scott Gramm

Manager, Renewable Natural Gas

FORTISBC

FortisBC is a major natural gas and electric utility company serving over 1.2 million customers across British Columbia. FortisBC has emissions reduction goals among the most ambitious of their kind in Canada, and are at the forefront of BC's renewable natural gas (RNG) expansion goals.

Scott Gramm is the manager of FortisBC's RNG program and has over 20 years of experience managing projects in the power, technology and gas industries.

John R. Kirkwood

Partner

FAEGRE BAKER DANIELS LLP

John Kirkwood has advised ethanol, cellulosic ethanol, green diesel, green jet, waste-to-energy, renewable, chemical and other developers and their investment banks in raising more than $5 billion of equity and debt to develop alternative energy and renewable chemical facilities. He is nationally recognized in the financing of renewable fuels, renewable chemical, biogas and other renewable projects using tax-exempt and taxable bonds. In 2017 Biofuels Digest named John one of the Top 100 People in the Advanced Bioeconomy.

John assists developers, lenders, investment banks and governmental entities in arranging debt and equity financing for the industrial biotechnology industry, including biofuels, renewable chemicals and related low-carbon clean energy, cleantech and bio-based products. He represents nationally recognized alternative energy and renewable chemical companies as well as investment banks, senior lenders, mezzanine lenders and equity providers in finance transactions for the industrial biotechnology industry.

John is experienced at securing grants and guaranteed loans from the U.S. Department of Energy ("DOE") and the U.S. Department of Agriculture ("USDA"), representing clients before the U.S. Environmental Protection Agency ("EPA") in developing pathways for renewable fuels to satisfy the federal biofuels mandate.

Mark Warner

Founder

WARNER ADVISORS

Warner Advisors is a consulting firm focused on delivering commercialization assistance for advanced technology clients in and food. Mark is a recognized leader in the area of renewable energy, biotechnology, biofuels, and biochemicals and has been selected as one of the Top 100 People in Bioenergy for multiple years. He has more than a decade of senior engineering and executive operational leadership experience within the advanced bioeconomy. Mark has delivered engineer and managerial support beginning at the bench level, progressing through pilot and demonstration stages, culminating in the construction, start-up and operation of commercial bio-economy facilities.

As Sr. Vice President of Engineering for Solazyme, Mark was responsible for world-wide deployment of technology and management and managed a portfolio of $200 million of commercialization projects. As Sr. Vice President Process Industries for Harris Group, Mark was responsible for conversion of biomass to fuel, fiber and chemicals. As Vice President of Engineering for Imperium Renewables, Mark was the senior corporate officer responsible for technology, engineering and construction of biodiesel production facilities for renewable energy. He was also the technical voice of the company to industry analysts, banks and venture capitalists during successful equity and project-finance debt fundraising that secured over $200 million in funding.

Ian Thomson

President

ADVANCED BIOFUELS CANADA

Advanced Biofuels Canada (ABFC) is Canada's national trade association promoting the production and use of low-carbon advanced biofuels. It is also a key contributor to federal and provincial fuels and climate policy, providing research-based advocacy to policy and regulatory development for over a decade. Formal working relationships connect it with North America's leading advanced biofuels and low carbon fuel trade associations. ABFC work is also informed by collaborative initiatives with Canada's leading energy NGOs and academics.

Ian Thomson is the President of ABFC and has over 25 years' experience in renewable fuels industry development. He has founded several biofuel industry associations and has expertise in policy implementation, market development, strategic planning and sustainability.

John F. Pierce

Partner and Firmwide Co-Chair, Clean Technology Practice

PERKINS COIE LLP

Perkins Coie is the 18th largest law firm in the U.S. Focused on the development and financing of energy and infrastructure projects, partner John Pierce represents clients in connection with power generation projects fueled by an array of traditional, renewable, and unconventional energy sources including biomass power and fuels (woody, green, algal, MSW), biomass to hydrocarbons, biogas, syngas and alternative fuels. John's alternative energy experience also includes production facilities for ethanol, advanced biofuels such as biodiesel and biojet, as well as representation of advanced biomaterials producers.

John has advised and structured various financings of energy and energy-related projects using a range of means. These include venture financings, private equity financings, non-recourse debt financing (syndications and clubs), bridging loans and convertible debt, portfolio and single project bond financings (IRBs, pollution control and other special purpose bonds), 144A financings, and governmental loan guarantees and grants. John is the co-founder and former Chair of the Algae Biomass Organization and of The Pacific Northwest Clean Tech Open.

Peter Vadas

Environmentally Integrated Dairy Management Research, Agricultural Research Service

Gene Lester

National Program Leader, Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA)

The Agricultural Research Service (ARS) is the chief research arm of the USDA, tasked with delivering scientific solutions to national and global agricultural challenges. The ARS leads 660 projects within 15 National Programs located across over 90 research locations around the world. With a $1.4 billion annual budget the ARS works to deliver cutting-edge, scientific tools and innovative solutions for farmers, producers, industry, and communities in support of agro-ecosystems, natural resources and economic competitiveness.

Cynthia Thyfault

Founder & Chief Executive Officer

GLOBAL BIOFUTURE SOLUTIONS

CEO Cynthia Thyfault has provided over 30 years of business management consulting for the development, management and funding of biomass conversion technologies, including biofuels, bio-chemicals, and bio-power, both domestically and internationally. She has supported development and deployment of over $3 billion of Low Carbon technologies and was recently was named one of the "Top 100 People in the Bioeconomy" Awards by the Biofuels Digest in 2016 and 2017.

Ms. Thyfault served as Chairman for the fourth charter on the Renewable Energy and Energy Efficiency Advisory Committee (REEEAC). REEEAC advises the United States Department of Commerce Secretary on competitiveness issues facing U.S. renewable energy and energy efficiency exports. The committee also provides advice on the development and administration of programs and policies to expand U.S. renewable energy, trade policy negotiations relating to U.S. energy efficiency exports. She is co-chairman of the Energy Subcommittee of the National Rural Lenders Association, which advocates for USDA Guaranteed Lending programs to support rural economic development. She also served on the Industry Working Group for the Bioenergy Standards for the Climate Bonds Initiative, and currently serves in the same position for the Electrical Grid Standards; the Business Development Committee for the Commercial Aviation Alternative Fuels Initiative (CAAFI); as the Finance Lead for the international outreach mission to the Australian Initiative for Sustainable Aviation Fuels (AISA) and The Aviation Initiative for Renewable Energy (AIRE).

Sebnem Madrali

Research Engineer

CANMET ENERGY

CanmetENERGY engages in research and development in the areas of energy efficiency, clean fossil fuels, and renewable and alternative energy sources, renewables and industrial processes. Our goal is to ensure that Canada is at the leading edge of clean energy technology development and greenhouse gas reduction.

With over 470 scientists, engineers, technologists, managers, and support staff, CanmetENERGY develops and operates science and technology programs and services, aimed at a low carbon future, and provides scientific and technical expertise in bioenergy and renewables.

Sebnem Madrali is a research scientist at Natural Resources Canada and the CanmetENERGY Engineering Projects Leader.

World Nieh

National Program Leader, USFS, Forest Products

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA)

The United States Forest Service is an agency of the United States Department of Agriculture that administers the nation's 154 national forests and 20 national grasslands, which encompass 193 million acres. As the lead Federal agency in natural resource conservation, the US Forest Service provides leadership in the protection, management, and use of the Nation's forest, rangeland, and aquatic ecosystems.

World focuses on USDA's cellulose nanomaterials technologies, renewable chemicals, policies and regulations for emerging technologies, and new technology deployment. Currently he represents the Forest Service in several interagency groups such as the National Nanotechnology Initiative Biomass R&D Board, and Advanced Manufacturing. He was awarded the 2008 William H. Aiken Research Prize.