

Contents

List of figures	VII
List of tables	XI
List of abbreviations	XV
List of units	XVII
1 Introduction	1
1.1 Research motivation, questions and scope	1
1.2 Approach and outline	5
2 Bio-commodities and cellulosic fuels	9
2.1 Agro-industrial production as part of process industries	9
2.1.1 Process industry characteristics	9
2.1.2 Agricultural and forestry production	13
2.1.3 Supply chains for bio-commodity production	15
2.2 Industrial use of agricultural and forestry raw materials	17
2.2.1 Drivers and criticism of industrial biomass use	17
2.2.2 Biomass sources and industrial applications	21
2.2.3 Characteristics of agricultural and forestry raw materials	24
2.3 Cellulosic fuels	28
2.3.1 Lignocellulosic biomass	28
2.3.2 Fermentation-based fuels and chemicals	32
2.3.3 Ethanol industry and markets	33
2.4 Summary and addressed issues	40
3 Economics of bio-commodity production	43
3.1 State of research on bio-commodity production economics	43
3.1.1 Definitions and research areas	43
3.1.2 Review of techno-economic assessment literature	49
3.1.3 Review of strategic supply chain design literature	54

3.1.4	Review of uncertainties and variability literature	62
3.2	Deductions from state of research	66
3.2.1	Literature review summary and conclusions	67
3.2.2	Development of a three step economic evaluation framework	68
3.3	Case study: fuels from sugar industry by-products in Australia	72
3.3.1	Fuel industry and markets in Australia	73
3.3.2	Regulatory environment and public discussion	74
3.3.3	Australian ethanol production and projects	76
3.3.4	The Australian sugar industry	78
4	Selection and modelling of production and logistics systems	83
4.1	Methodology and approach	84
4.1.1	Technology selection	84
4.1.2	Technology modelling for agro-industrial supply chains	85
4.1.3	Investment and cost estimation for process industry production systems	90
4.1.4	Investment evaluation and discounted cash flow analysis	99
4.1.5	General modelling assumptions and determinations	106
4.2	Feedstocks: Harvest and milling by-products	110
4.2.1	Milling residues: surplus bagasse	111
4.2.2	Harvest residues: sugar cane trash	112
4.3	Logistics	114
4.3.1	Storage	115
4.3.2	Road transport	118
4.3.3	Rail transport	121
4.3.4	Ship transport	123
4.4	Pre-processing	125
4.4.1	Pelletisation	126
4.4.2	Torrefaction	131

4.4.3	Pyrolysis	136
4.5	Fuel production	141
4.5.1	Feedstock handling and lignocellulose pre-treatment	143
4.5.2	Saccharification, fermentation and product recovery	144
4.5.3	Fuel distribution	149
5	Supply chain design	151
5.1	Methodology and approach	151
5.1.1	Overview strategic supply chain design	151
5.1.2	Sequential approach with pre-selection and optimisation	156
5.1.3	Optimisation of feedstock sourcing	158
5.2	Data and assumptions for the Australian sugar industry	164
5.2.1	Feedstock supply quantities and locations	165
5.2.2	Fuel processing locations for centralised design	167
5.2.3	Logistics infrastructure and options	170
5.2.4	Potential pre-processing strategies	172
6	Uncertainty and variability analysis	175
6.1	Methodology and approach	175
6.1.1	Scope of the uncertainty and variability analysis	176
6.1.2	A nested Monte Carlo simulation approach	180
6.2	Simulation assumptions and determinations	187
6.2.1	Identification of critical simulation parameters	188
6.2.2	Stochastic simulation of lifetime constant parameters	194
6.2.3	Stochastic simulation of lifetime varying parameters	204
6.2.4	Simulation output measures and expected results	218
7	Case study results and discussion	221
7.1	Results of the deterministic simulation	221
7.1.1	Base scenario: decentralised fuel production	221
7.1.2	Base scenario: centralised fuel production	222

7.1.3	Analysis of other scenarios	230
7.1.4	Intermediate products	237
7.2	Results of the stochastic simulation	239
7.2.1	Impacts of uncertainty and variability	239
7.2.2	Performance of the deterministic supply chain design	242
7.2.3	Robustness of the deterministic supply chain design	243
7.3	Discussion of results	245
7.3.1	Summary of the case study results	246
7.3.2	Evaluation of project economics	247
7.3.3	Comparison with other estimations	252
7.3.4	Implications for cellulosic ethanol production	253
7.3.5	Implications for bio-commodity production in general	255
8	Transfer and critical review of findings and approach	257
8.1	Transferability of the research framework	257
8.1.1	Other technologies: Fischer-Tropsch fuel	258
8.1.2	Other feedstocks and regions: a Pacific supply chain	263
8.2	Placement of the work in the broader research field	267
8.2.1	Limitations of the presented simulation and methodology	267
8.2.2	Suggestions for further research	271
9	Summary and outlook	273
9.1	Summary of simulation results and conclusions	273
9.2	Outlook	275
	References	277
	Appendix	319
	Acknowledgements	331