Creating, Negotiating and De-Risking Biomass Feedstock Supply Chains: Traditional Approaches versus New Developments

Advanced Bioeconomy Feedstocks Conference

Miami, FL

June 7-8, 2016

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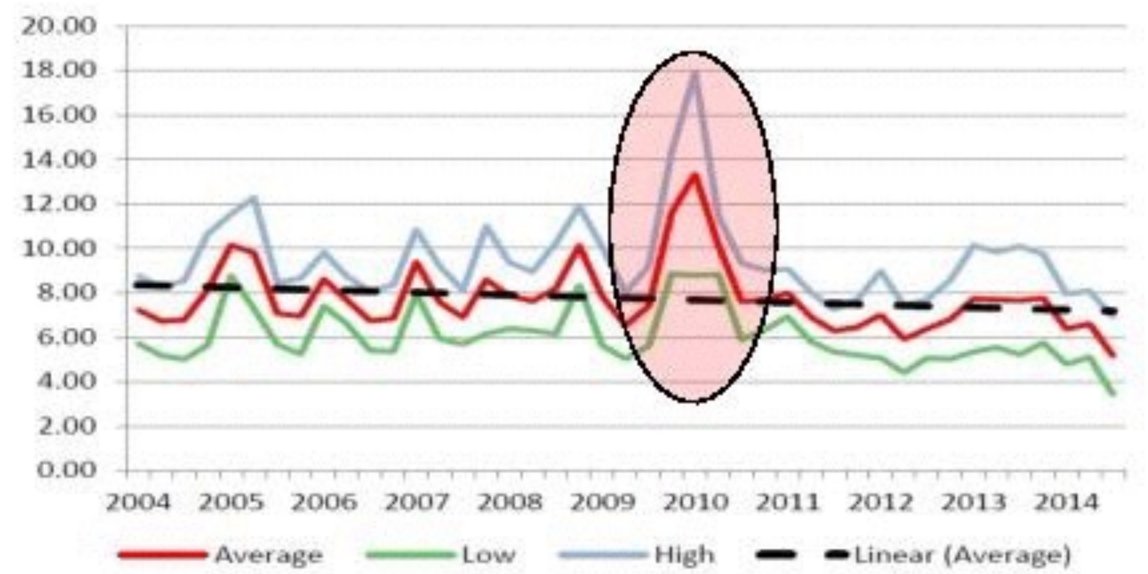
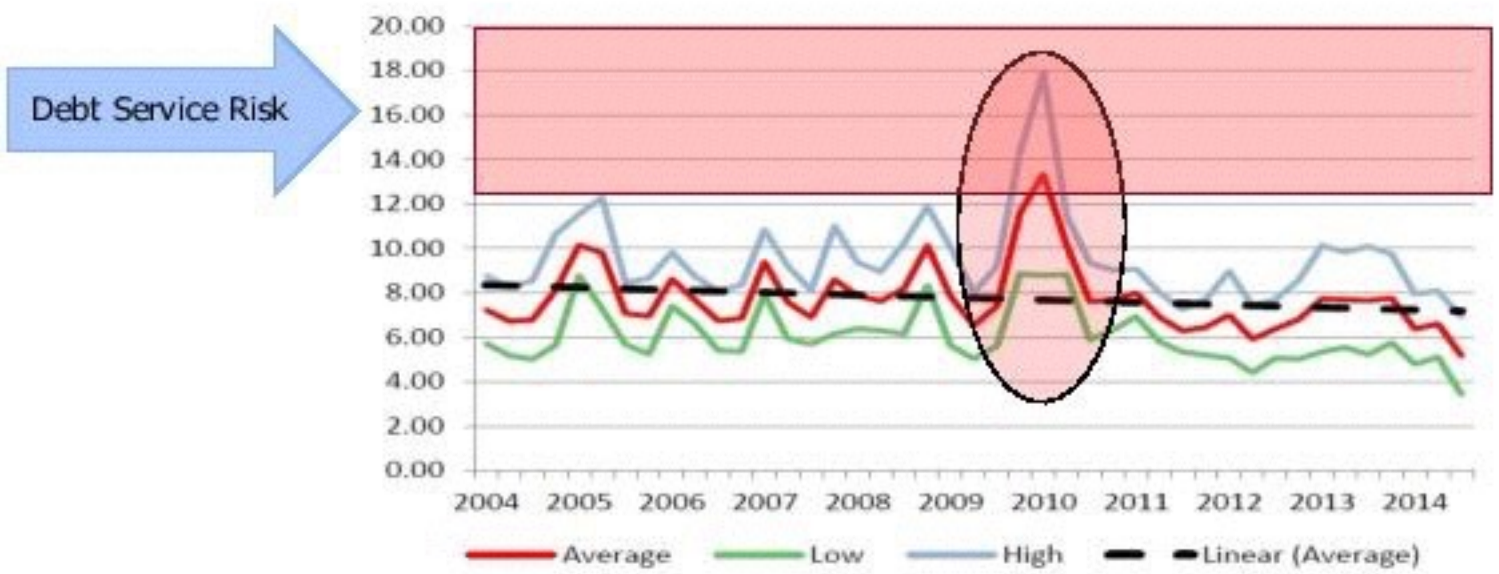
How do you predict this?

Figure 5: 10-year Historical Nominal Cost of Pine Pulpwood Stumpage (Present $/ton)



Why is this Important?

Figure 5: 10-year Historical Nominal Cost of Pine Pulpwood Stumpage (Present $/ton)



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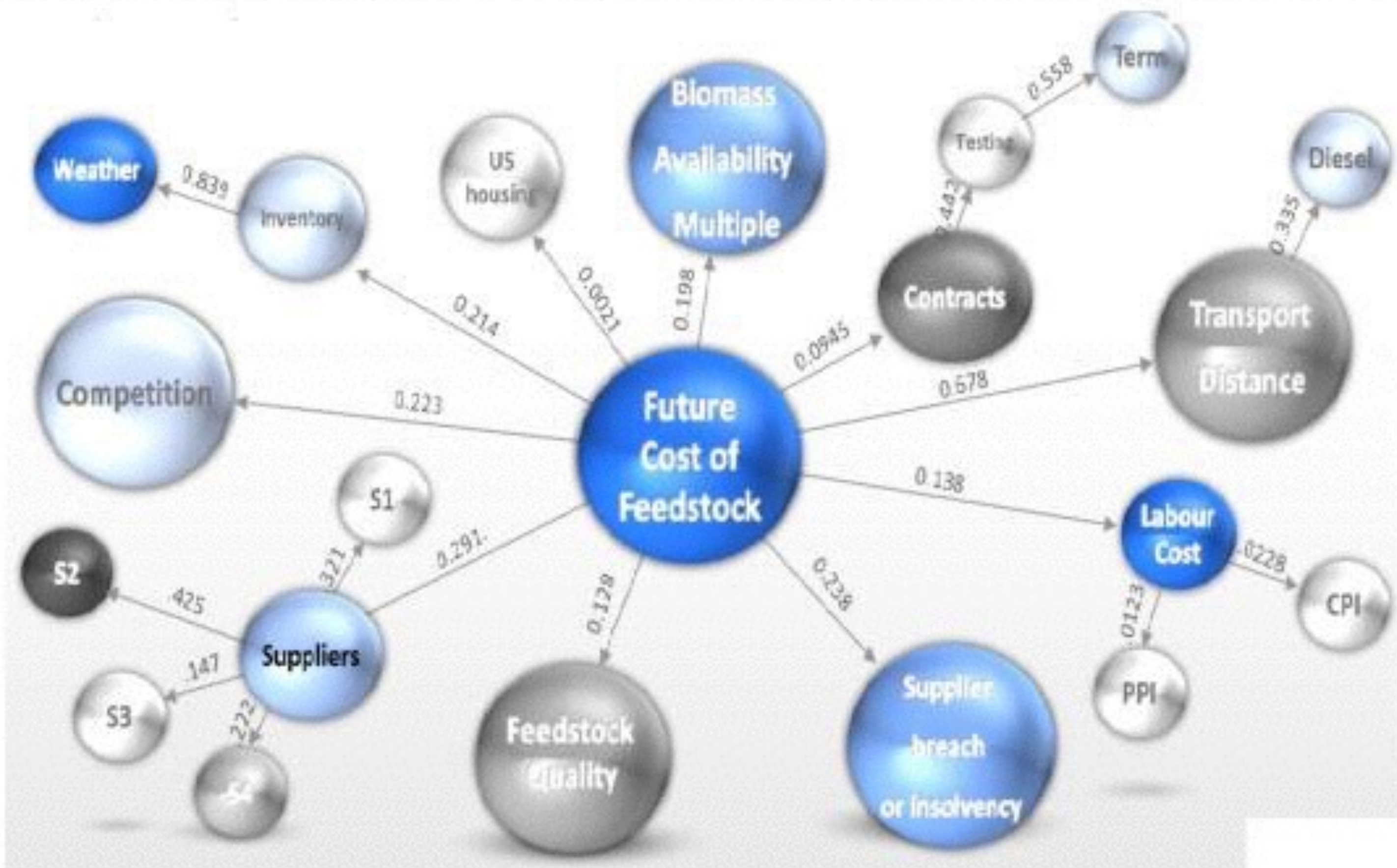
Biomass Supply Chain Risk: Complexity

Multiple components with indeterminate risk of occurrence and impact



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Would you trust this?

$$\Delta G = (V^{L-L}_{\text{bound}} - V^{L-L}_{\text{unbound}}) + (V^{P-P}_{\text{bound}} - V^{P-P}_{\text{unbound}}) + (V^{P-L}_{\text{bound}} - V^{P-L}_{\text{unbound}} + \Delta S_{\text{conf}})$$

$$V = W_{\text{vdw}} \sum_{i,j} \left(\frac{A_{ij}}{r_{ij}^{12}} - \frac{B_{ij}}{r_{ij}^{6}} \right) + W_{\text{hbond}} \sum_{i,j} E(t) \left(\frac{C_{ij}}{r_{ij}^{12}} - \frac{D_{ij}}{r_{ij}^{10}} \right) + W_{\text{elec}} \sum_{i,j} \frac{q_i q_j}{\varepsilon(r_{ij}) r_{ij}} + W_{\text{sol}} \sum_{i,j} (S_i V_j + S_j V_i) e^{(-r_{ij}^2/2\sigma^2)}$$

So… how do we solve for uncertainty in the supply chain?

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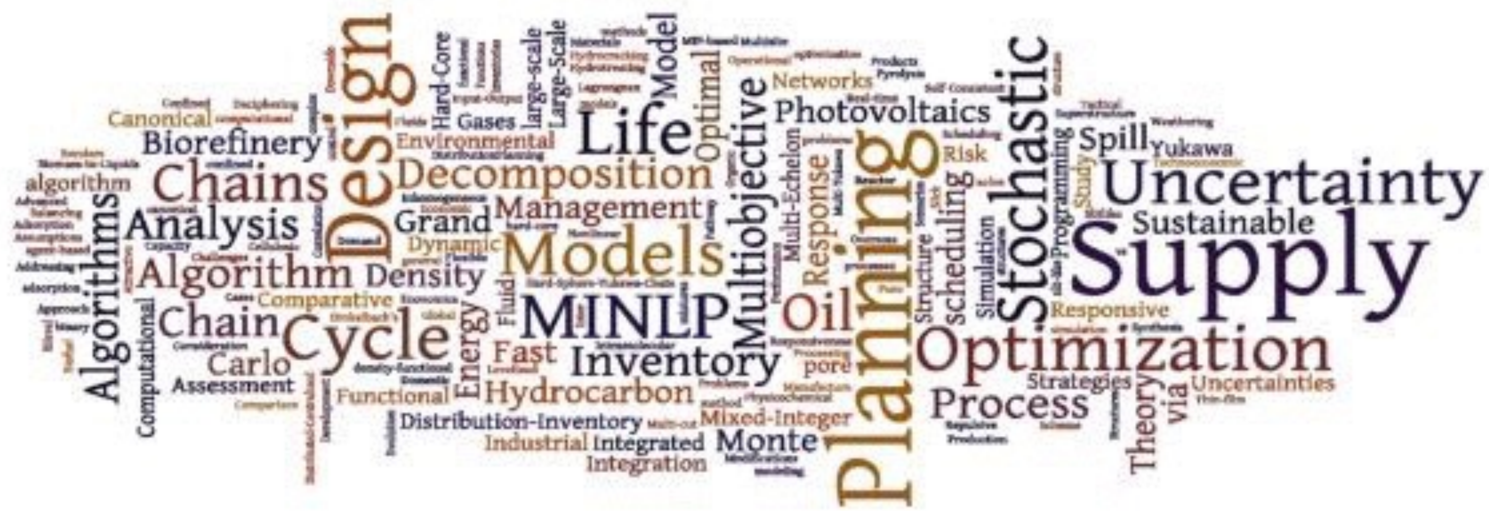
Complexity x Uncertainty = "Best Guess"



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In the real world, questions about feedstock risk are simple

- What is the likelihood that feedstock price will exceed $74 per bone dry ton over the next 10 years?
- How big is too big? What is the ideal plant size?
- What are the real risks to the feedstock supply?
- What is the vulnerability of the supply chain to a disruption risk?
- Which particular variable has the largest impact upon feedstock cost?
- What is the impact of various mitigation strategies on multiple disruption risks?
- What is the ideal supplier mix to minimize risk and cost?

The fact is that 10 experts can give 10 different opinions.

So.... What makes for reliable predictions in biomass feedstock?

And ... When do you know you can trust the information?


40
20
0
340
320
300
100
200

Impact Analysis :
Current and Additional Consumption on Supply

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Results

Description (US Short Tons)	Amount	Reference
Growth Drain Ratio (R2)	2.2	R2 = S16 / D6
Available Annual Supply (R3)	**2,600,000**	R3 = S16 - D6
Sustained Annual Harvest Plus Net Growth (S16)	4,800,000	S16 = S7 + S15
% Annual Net Growth after Removals (R1)	**2%**	R1 = S15 - S3
Annual net Growth after Removals (S15)	600,000	S15 = S14 - S3
Sustained Annual Pulpwood Harvest (without net growth) (S7)	4,300,000	S7 = S5 x S6
Competitive Annual Consumed Tons (D6)	**2,200,000**	D6 = D5 x D3
Annual Pulpwood Available for Harvest (S5)	8,700,000	S5 = S3 x S4
Total Ending Pulpwood (after removals plus growth) (S14)	32,100,000	S14 = S11 + S13
Total Beginning Pulpwood (S3)	31,500,000	S3 = (S2c / 100) x 3.37

References:
S = Supply
D = Demand (Consumption)
R = Results

Summary

Diameter Classes by Dbh		FIA Pulpwood Data (only pulpwood trees ≥5.0" to 10.0" dbh inside each 2" dbh average quadratic mean class)			Total Beginning Pulpwood	Annual Pulpwood Available for Harvest		Sustained Annual Pulpwood Harvest (without net growth)	
S1		S2a	S2b	S2c	S3	S4	S5	S6	S7
US dbh inches		S2c / S2c sum	FIA	S2b x 1,000,000	(S2c / 100) x 3.37	chart	S3 x S4	chart	S5 x S6
2" Class	Range	Percent	US Cubic Foot (million)	US Cubic Foot	US Tons	Percent	US Tons	Percent	US Tons
6	5.0-6.9	25%	236.4	236,400,000	7,966,680	4%	339,151	22%	74,285
8	7.0-8.9	48%	451.1	451,100,000	15,202,070	36%	5,510,189	34%	1,897,079
10	9.0-10.9	25%	230.3	230,300,000	7,761,110	34%	2,674,550	80%	2,134,715
12	11.0-12.9	2%	15.0	15,000,000	505,500	32%	163,782	93%	152,936
≥ 14	≥ 13.0	0%	3.3	3,300,000	111,210	31%	34,201	93%	31,940
		100%	936.1	936,100,000	**31,546,570**		8,721,873		4,290,955

Diameter Classes by Dbh		Pulpwood After Annual Harvest	Growth Shifting Dbh Classes		Total after Removal Plus Dbh Shift (before growth)	Growth Inside Dbh Classes		Total Ending Pulpwood (after removals plus growth)	Annual Net Growth after Removals	Sustained Annual Harvest Plus Net Growth
S1		S8	S9	S10	S11	S12	S13	S14	S15	S16
US dbh inches		S3 - S7	chart	S8 x S9	(S8 - S10) + S10 preceding dbh	chart	(S8 - S10) * S12	S11 + S13	S14 - S3	S7 + S15
2" Class	Range	US Tons	Percent	US Tons	US Tons	Percent	US Tons	US Tons	US Tons	US Tons
6	5.0-6.9	7,891,685	37%	2,925,569	6,800,039	23.5%	1,168,360	7,968,399	1,719	76,004
8	7.0-8.9	13,305,540	23%	3,002,159	13,228,949	12.8%	1,321,540	14,550,490	(651,580)	1,245,498
10	9.0-10.9	5,646,472	19%	1,091,157	7,557,474	10.5%	477,438	8,034,912	273,802	2,408,518
12	11.0-12.9	351,025	19%	66,628	1,375,554	7.6%	21,727	1,397,282	891,782	1,044,717
≥ 14	≥ 13.0	79,734	0%	-	146,361	5.6%	4,486	150,847	39,637	71,578
		27,274,455		7,085,513	29,108,378		2,993,552	**32,101,930**	555,360	4,846,315

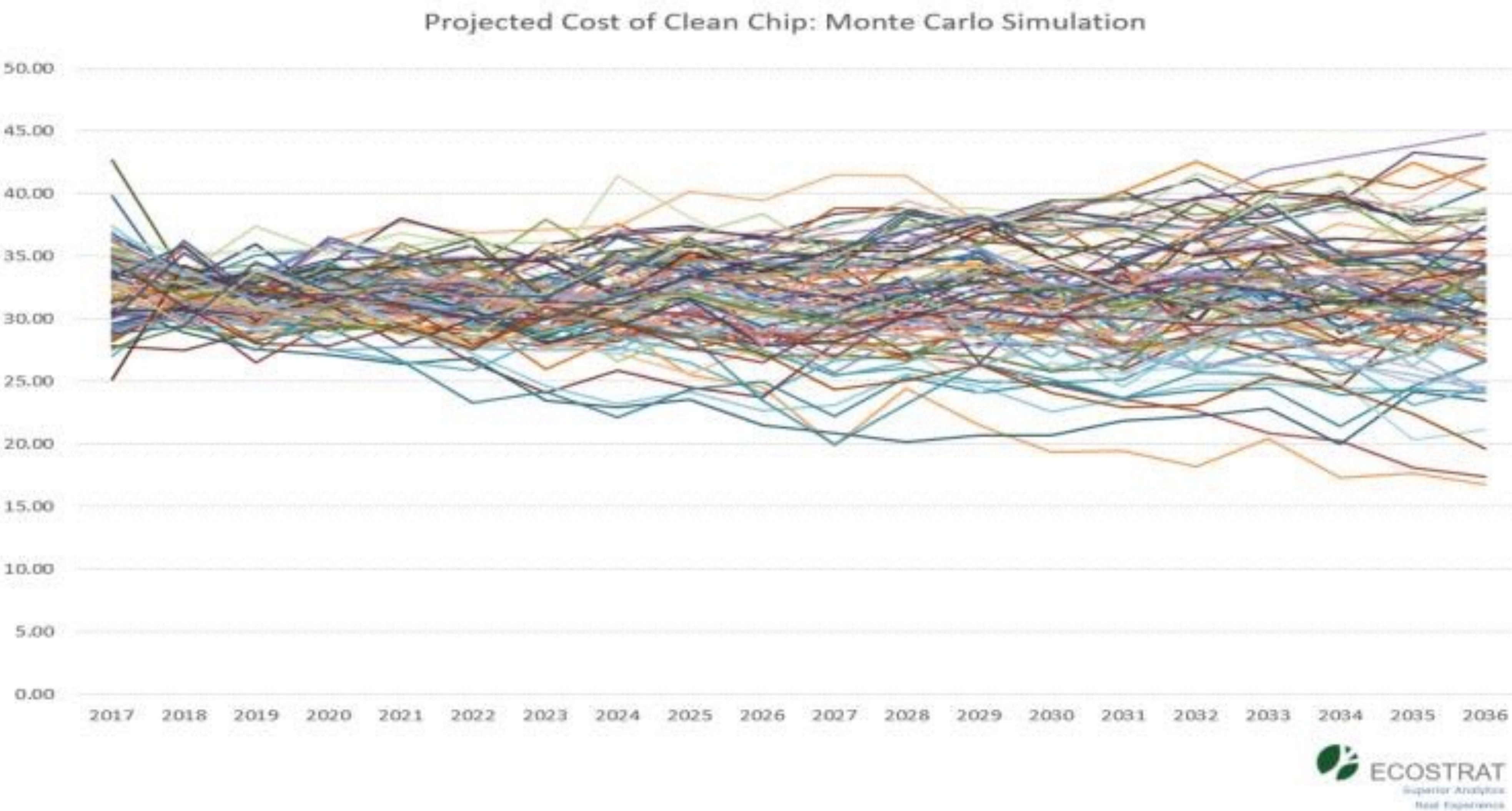
% Annual Net Growth after Removals (R1 = S15 / S3): 2%

% of total Beginning Pulpwood (S16 / S3): 15.4%

Weighted Mean Average Biological Growth Cross-Check (refer to chart "Growth Percent"): 14.9%

% Variance between two methods (variance less than "1%" no adjustments required): 0.44%


NOWHERE


Projected Cost of Clean Chip: Monte Carlo Simulation
50.00
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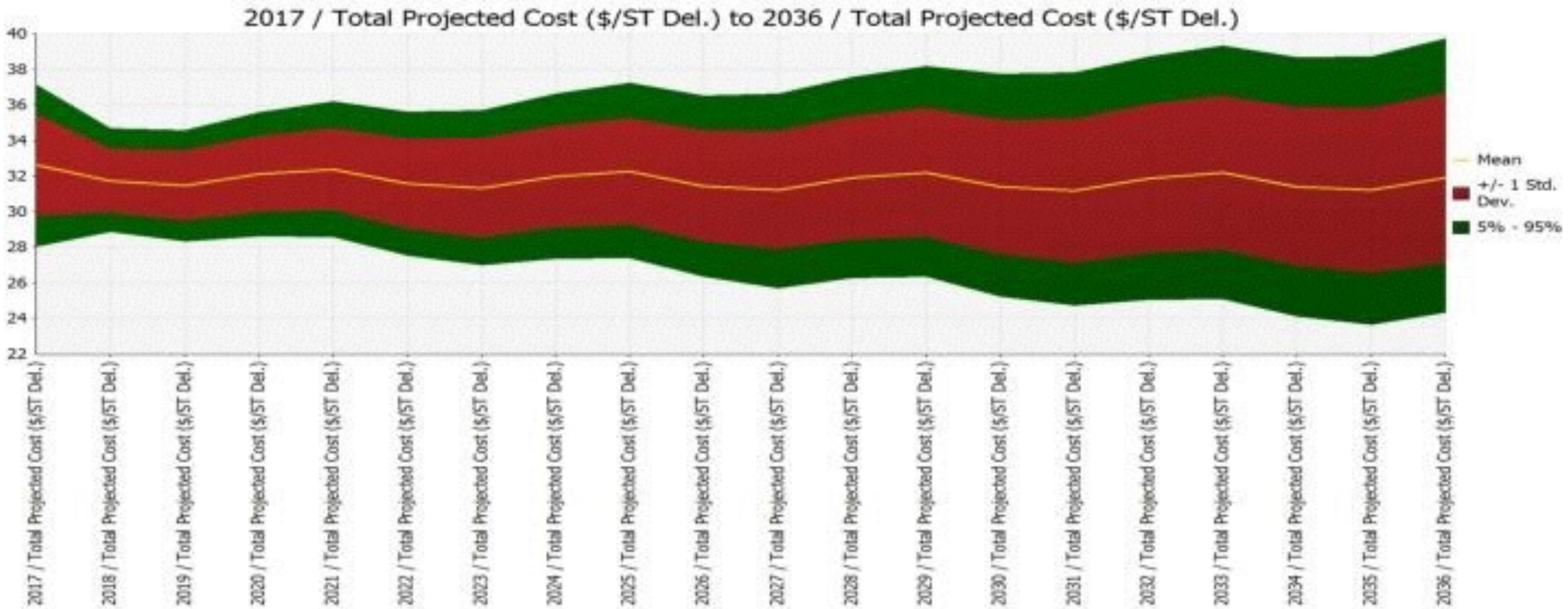
Projected Clean Chip Cost – 10,000 scenario iterations



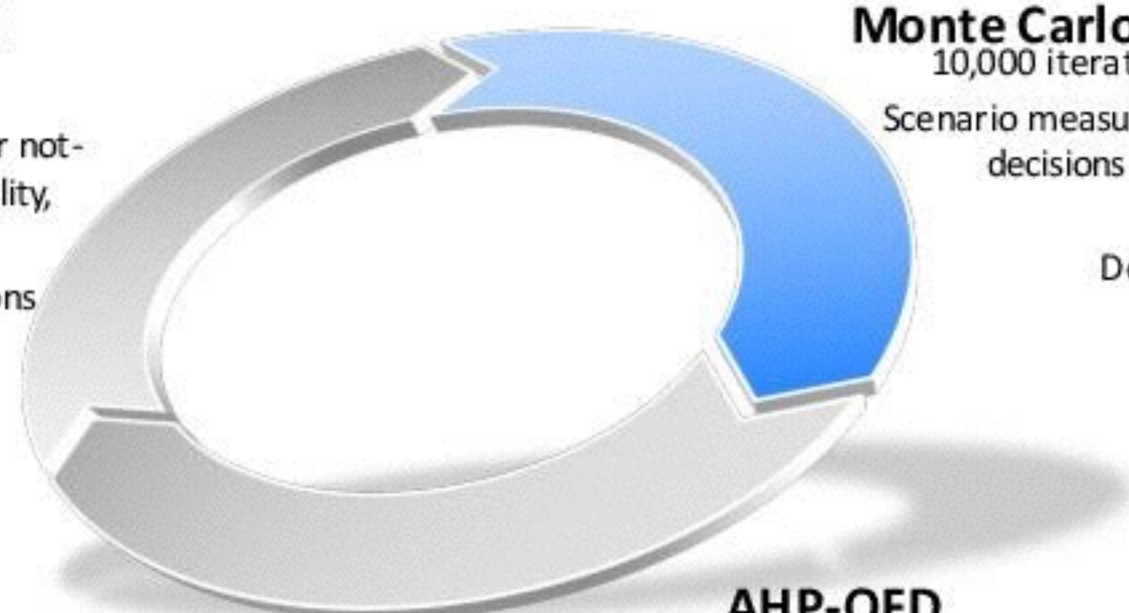
New Approaches Are Needed

Combined "Model-Layering" approach gives industry-leading predictive accuracy

Chance-Constrained Optimization

Feedstock constraints: 10 year not-to-exceed cost, feedstock quality, shortage.

Optimal management decisions regarding feedstock?



Monte Carlo Validation

10,000 iterations per variable

Scenario measurement of supply decisions against projects constraints

Decision validation

AHP-QFD

Identificaton of suppliers, feedstock avialability, capacity, quality criteria, price.

Supplier Performence Score

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AHP-QFD
Supplier Score and Weightings

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Supplier scores and weightings

Evaluating criteria	Evaluating criteria importance score	Demolition wood	Refuse derived fuel	Wood chips	Olive residues	Wood Pellets
Long term contracts	0.0226	8	0	2	7	1
Take or pay clauses	0.0539	5	6	0	10	7
Track record	0.1098	5	4	3	4	5
personal relationship	0.0125	4	6	9	7	2
Contract has PFI back up	0.0131	2	7	0	6	8
Fixed price	0.0571	8	5	8	7	3
Traceable (chain of custody)	0.0169	5	6	4	6	1
Base cost of material (£/MWh)	0.0684	5	7	1	8	5
Clear definition of fuel	0.0098	6	5	0	4	7
Visibility	0.0132	2	0	10	10	6
Quality control mechanisms in place	0.0034	3	5	1	6	2
Guarantee of fuel quality available	0.0529	2	10	4	10	9
Supplier stability (in biomass market)	0.0061	0	0	5	9	1
Distance from buyer	0.0008	4	1	5	3	9
CO_2/MWh	0.0779	2	4	3	7	5
Land use change	0.0327	1	10	0	7	8
FSC accreditation	0.0116	4	4	6	6	9
Alternative end use (best use of biomass)	0.0196	7	0	4	7	7
Diversion of material from landfill	0.0411	4	6	10	8	3
Environmental regulatory environment in which the supplier operates	0.0068	9	5	9	7	4
Performance against sustainability assurance certificate indicators	0.0145	0	1	9	10	6
Credit strength	0.0398	2	9	4	7	8
Size of balance sheet	0.0172	2	2	1	10	6
Financially robust or credible counterparty	0.1490	2	7	3	1	2
Rural jobs created or safeguarded	0.0919	5	8	1	1	3
Dependency on imports	0.0066	8	4	6	0	8
SME employment created	0.0459	8	9	3	6	2
Biodiversity change	0.0053	4	6	4	10	1
Total	1.000	117	137	115	184	138
Normalized score		0.176	0.269	0.141	0.225	0.188
Rank		4	1	5	2	3

Chance Constrained Optimization - Setting Constrained Limits for Feedstock Quality

Quality criteria of fuels according to technology provider.

Criteria	Unit of measurement	Comments
Biomass energy content	%	To qualify for renewable energy financial incentives the bioenergy content of the fuel must be over 90% (UK only)
Moisture content	Percentage weight (wt%)	The amount of water in the material can affect efficiency and corrosion of the conversion process
Lower heating value (energy content)	Megajoules per kilogram (MJ/kg)	The energy density of the material affects the efficiency and operating hours of the conversion plant
Ash content	wt%	The non-combustible fraction of the fuel can cause problems associated with corrosion and clogging of feed mechanisms
Non-metal impurities: sodium (Na), potassium (K), fluorine (F)	mg/kg	Under certain conditions these elements can lead to the creation of corrosive acids and are controlled under emissions regulation
Aluminium (Al)	mg/kg	Can lead to corrosion of equipment and are tightly controlled under emissions regulations

Probability of Exceeding Feedstock Price Cap: 100,000 Scenario Simulation

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The Impact of Better Modeling of Risk

- Accelerate the rate of bioenergy project development in North America
- Enables creation of more effective risk mitigation strategies by management
- Enables better pricing of risk by commercial lenders and debt providers
- Increase the credit rating of bioenergy projects
- Decrease financial drag on bioenergy/ lower debt and capital cost
- Accelerate the development of insurance based mechanisms to offload project risk (such as Biomass Supply Chain Insurance)

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To discuss your project please contact us

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