White Paper (draft v6):

Pricing Second-Generation (2G) Cellulosic Bioethanol (CEtOH) Products via Integrated Techno-Economic Project Finance Analysis Incorporating Net Present Value (NPV) and Monte Carlo Simulation Analysis

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Abstract

This white paper proposes a method for gaining insight into prospective market pricing thresholds for advanced (2G) bioethanol products and services. The paper proposes a structured, customer-focused, integrated approach to model advanced bioethanol plants as a way to isolate and determine the component value-add of proposed product innovations as an aspect of customer Net Present Value (NPV). As well, it is recommended that the NPV analysis be enhanced with stochastic (Monte Carlo) analysis in order to determine price elasticity (based on plant profit volatility) and to provide sensitivity analysis guidance for risk management. A thorough discussion of the logic for this approach is provided.

1. OVERVIEW

A number of innovative start-up firms, as well as divisions of larger firms, are currently pursuing options for commercializing advanced product innovations for producing second-generation (2G) bio-ethanol. This white paper provides guidance on prospective market price analysis for such innovations. The proposed approach should be of particular interest to companies assessing the development and commercialization of innovative 2G bioethanol products for which there are currently few market price reference points.

2. 2G PRODUCT VALUATION CONSIDERATIONS

As the 2G bioethanol products and services market is at the bleeding edge of development in the bioethanol industry, pricing products and services within the still-evolving value chain raises particular challenges. The bulk of competitive 2G products are still in development, meaning that formal commercial market pricing reference points are still pending. Companies considering the development and commercialization of 2G bioethanol products face a vexing chicken-and-egg quandary: to invest speculatively in R&D, hoping to achieve a particular ROI as a first mover, or to wait until early movers demonstrate market feasibility, but to potentially sacrifice early market share as a result.

Ostensibly the value-add of any new ethanol production product or service is the simple cost productivity delta margin: the relative amount of ethanol produced at a lower aggregate cost in comparison to a lower-performing reference. Without strong competitive market indicators, the fall-back is to compare to the productivity of full-scale W1 variant plants in terms of aggregate productivity.

However, as detailed below, the integrated nature of the agents in the plant design, financing, and operation complicates the ability to extract pricing guidance based on a simple *product-cost-to-productivity* metric. The productivity of the operating plant as a whole (in terms of equipment, processes and operation) shifts throughout to accommodate particular major product innovations in a unified production chain from pretreatment to distillation. For instance, unique microbial and enzymatic agents for the production of advanced bioethanol demand particular unique processes and equipment which shift the profitability of the plant as a whole. A significant product or service innovation for advanced bioethanol plants results in a unique net profit profile via a combination of integrated risk reduction, productivity gain, capital expenditure (CAPEX), and operating expenditure (OPEX) factors.

The term ‘product-process cost complex’ can be used to describe the notion that comparative agent pricing must accommodate the full operating scope of the plant. The operating plant can be considered from this standpoint as a complex optimization of the products (i.e. microbial or enzymatic agents) operating *in situi* with related processes, equipment, production parameters, and financing factors.

2.1. Production Efficiency Principle

At base the value of 2G bioethanol products such as microbial and enzymatic agents is the cost saving realized in terms of proportional financial (i.e. $ or €) cost per gallon/liter of ethanol produced. Simply, a higher production yield resulting from the same plant due to the product innovation package specifies a profit upside for the plant operator which then suggests an *inelastic market price upside* potential for the efficiency agents on the open market (yeast / enzyme product, for example).

However, as the agent used, particularly in innovative emerging 2G processes, influences plant design, financing, and operation, a highly integrated analysis must be conducted to establish a truly transferable efficiency principle.

2.2. Operating Expenses (OPEX) Breakdown

The cost breakdown per gallon/liter of bioethanol produced is broader than the simple annual manufacturing and material costs. Bioethanol is a highly cost-sensitive product as most plants are marginally profitable and challenged by volatile material costs, preeminently feedstock in its *crush margin* association with the volatile selling price of ethanol. Feedstock commodity cost volatility can be hedged (controlled), but cannot be programmed out completely. The set of OPEX considered therefore should include the full-range of variable items such as administrative and selling-associated labor, insurance, feedstock storage and handling, property tax, and plant maintenance costs.

2.3. Capital Expenses (CAPEX) Breakdown

As particular production agents require a specific process, plant equipment often must be customized to the particular process design. CAPEX for the plant construction (or upgrade in the case of re-engineering) and equipment are thus particular to the optimal process being targeted. Implementation overhead is crucial in terms of timeline: speed-to-deployment has a strong effect on operating profitability when considered in terms of long-term discounted cash return. Once tied to the particular product-based process cost profile, the CAPEX can be considered an embedded, accompanying cost to the 'product-process cost complex'.

2.4. Financing Factors

The approach to financing the plant CAPEX (build or upgrade) is significant to the long-term relative health of the plant. Considerations include debt-to-equity ratio, debt servicing costs, grants / subsidies utilized, depreciation schedule, leasing versus owning plant components, and tax basis. It is assumed that given a set of variable financing options, an optimal set exists for that particular plant outside of unpredictable risk factors such as interest rate and currency exchange volatility (which can be hedged but not removed). As such, financing variation between plants can be cancelled out as a plant-specific factor by utilizing the same financing approach and assuming the same volatility profiles for key uncertain factors.

2.5. Profit Factors

Roughly equivalent to feedstock impact, the variable cost of the ethanol sales price is a crucial co-determinant of plant profitability. The CBOT Corn Crush Margin establishes a formal market instrument for the ratio between corn and ethanol prices (http://www.ethanolmarket.com/PressReleaseCBOTCornCrush). Similar to feedstock, ethanol sales prices can be hedged (controlled via derivative instruments, chiefly commodity options and futures) to some degree, but not fully hedged-away in the long term. Also, the level of hedging restricts upside and has a downward effect in terms of transaction costs for hedging instruments. Again, by assuming the same volatility assumptions on ethanol selling price, this factor can be cancelled out in cross-comparison across two unique plants (while accommodating unique subsidy uncertainty factors in the case of a 1G plant versus a 2G plant).

3. RECOMMENDED VALUATION APPROACH

Given the need for a holistic plant analysis and the absence of cross-comparable operating 2G reference plants with comparable commercialized agents on the market, it is proposed that *stochastic simulation-based* (i.e. Monte Carlo-based) Net Present Value (NPV) analysis be used as a universal cross-equalizer in establishing the relative, transferable efficiency value of the 2G products (i.e. yeast and enzyme agents). Further, it is proposed that the foundation for the NPV analysis be a structured 'Project Finance' approach, which focuses on the perceived product value perspective of the customer.

3.1. Project Finance Perspective

As a sub-discipline of Finance, and as distinct from Corporate Finance, Project Finance is focused on: 1) cash flows, 2) stakeholder segmentation, and 3) explicit risk identification and allocation. By explicitly identifying and segmenting risks, Project Finance is especially useful in programming-out agency factors between stakeholders (i.e. partners, customers, financiers) in value analysis. Corporate Finance as a discipline, by comparison, is focused on financial analysis and decision making from a corporate perspective. It focuses on shareholder value creation and thus the simple agency motivation logic of corporate profit maximization.

In the case under evaluation, there is a desire to determine a product pricing base-line for a new 2G bioethanol technical production innovation. From the Corporate Finance perspective, the de facto guidance is to charge the highest rate that the hypothetical market will bear. As well, there is a desire to reduce risk to the lowest extent possible (i.e. delaying product release to gather more information, extracting optimal concessions in partnership arrangements, etc.).

However, given intrinsic technical and market uncertainties, the danger of the 'highest hypothetical price and lowest possible risk' perspective is that corporate agency interests run the risk of over-pricing a new innovation and thus missing a market opportunity. The Project Finance perspective views customers as an independent agent who will tend to make rational value choices based on perceived risks versus profit opportunities. By undertaking segmented Project Finance analysis of an operating ethanol plant, the intrinsic value-add perspective of the customer is adopted when considering product pricing.

The associated Project Finance methodology views the utilization of a new product within the operating context of the customer as a self-standing capital project with a unique NPV. In this case, the use of a new set of bioethanol products (i.e. microbial or enzymatic agents) is situated within an analysis of an operating customer bioethanol plant. The plant is treated as a self-standing project which is financed, built or upgraded, operated, depreciated, and which has a projected terminal value. In this way, the component value of the agents as a product is situated, in both economic and technical terms, within the embedded operating plant.

3.2. Plant Scenario Equalization: NPV Analysis

It is proposed that when a plant has been roughly equalized across all unique factors, including the introduction of both universal (i.e. commodity price volatility for feedstock costs and ethanol / byproduct sales price less subsidies) and plant-specific factors (i.e. financing terms, subsidy, CAPEX profile), the NPV-upside has been optimized to focus on the unique value contribution of the 'product-process cost complex'.

Two different plant configurations thus can be compared, in a *differential equation* sense, by equalizing scale to pinpoint an operating upside from the holistically integrated agent package employed. The use of the NPV approach acts to 'cancel-out' non-agent related factors in determining aggregate, holistic plant profitability over a defined period. For a particular investment cost and identical operating timeframe, the NPV outcome is the ultimate arbitrator of realized value from the customer perspective for two different processes / plants.

3.3. Stochastic Analysis: Monte Carlo Simulation

The use of stochastic analysis (i.e. Monte Carlo simulation[1]) addresses variation in both: 1) common (universal) uncertainties (such as commodity price volatility), and 2) unique uncertainties (such as subsidies and technical risks unique to the particular plant). Applied to the static NPV case, stochastic NPV analysis supplements the 'most likely' NPV valuation of the operating plant over time with guidance on: 1) volatility (standard deviation), 2) skewness (non-normality), and 3) key sensitivities (a reading on the relative strengths of each uncertain variable in influencing NPV upside or downside).

In terms of pegging *product price elasticity*, the NPV aggregate volatility (standard deviation dispersion in possible NPV outcomes) resulting from stochastic analysis can be considered a proxy. In practice, a 2G plant would involve more 'unknown' variables in stochastic simulation when compared to the relatively known quantity of 1G plant operation. A 2G plant would result in a higher uncertainty based upon unknowns associated with the innovative 2G 'product-process cost complex'. The resulting higher relative standard deviation in NPV outcomes would then suggest higher elasticity in product pricing, meaning a rational customer would demand a lower price premium to accommodate the risk they would be taking on by adopting the still emerging 'product-process cost complex.

[1] Monte Carlo analysis has a mathematically similar evaluative outcome to Real Options-base analysis (i.e. Decision Tree, Binomial Tree, or Black-Scholes analysis). The benefit of a Monte Carlo approach is that it allows direct volatility analysis of NPV outcomes, allowing for direct simulation of risk factors. Real Options Analysis, while *in theory* issuing nearly identical guidance when uncertainties are situated appropriately, is a methodology which allows better oversight of scenario-based uncertainties for managerial decision making guidance (i.e. decisions to apply different scales, assessing legal risk, etc.).

4. SPECIAL CONSIDERATIONS

4.1. New Technology Risk

In order to demand a higher market price, the 2G agents must result not only in a higher aggregate NPV from the holistic operating plant, but the NPV upside should also be high enough to accommodate the risks associated with the new technology. A principle of stochastic analysis applied to new technology initiatives is that future development will result in more information which will reduce the variability of outcomes in key simulation variables. In other words, over time, development of the new technology will yield better information which will reduce risks in aggregate NPV variability.

4.2. Market Timing

When considering 'market capture' (the ability of early movers to capture market share), there is a theoretical 'sweet spot' whereby a product is introduced early (assumedly with incomplete information on performance) in order to capture market upside in the future. It is assumed that in the early phase of an evolving market, those movers able to take informed risks by introducing new products at an attractive theoretical price, even when assuming some risk themselves, stand to potentially capture market share and subsequently raise prices once a customer-base has been captured. This can be considered a particular feature of the 2G bioethanol market in that there is a heavy presumed up-front investment and commitment from the customer perspective. Product providers able to accommodate (offload customer) risk via their business model stand to capture early market share.

4.3. Deployment Scenario: Full-Scale vs. Add-On

Opportunities for establishing rapid demonstration-scale implementations to prove efficiency and thus reduce NPV-upside volatility / uncertainty can be considered direct investments in reducing product pricing elasticity risk associated with the uncertain technology. Additionally, to the degree up-front CAPEX investments required are minimized, such as in the case of a hybrid plant 2G 'add-on' as opposed to a full-scale 2G plant, the opportunity to establish greater performance certainty to customers *AND* to demonstrate an 'on ramp' scenario can be considered a strong strategic play (in that the overhead of the dual goals of capturing uncertain customers and reducing performance uncertainty are addressed with reduced proportional deployment risk).

4.4. Subsidy Uncertainty

The uncertainty of government credits and subsidies has been raised previously in discussion. In the case of a 2G bioethanol plant project, this is a critical consideration as an assumed ethanol price subsidy is involved which is crucial to meeting NPV targets on an advanced plant. It is recommended that any uncertainty in subsidy provision be explicitly programmed in the stochastic simulation analysis[2]. Any doubts concerning continued subsidy will result in lower aggregate NPV, reflecting the risks. Notably, from the customer NPV perspective, gaining more subsidies over time may be an incentive to early adoption (from a time-value of money perspective).

5. MODELING AND ANALYSIS APPROACH

5.1. Comparative Scenarios

Two scenarios were modeled as NPV cases in order to practically demonstrate the approach:

1) 1G Corn Ethanol Plant (Dry Mill)
2) 2G Stand Alone CEtOH[3] Plant

5.2. Cancellation Principle

As per previous discussion, a concerted attempt was made to equalize the two models where common elements were concerned: 50 mgy scale, 65% E / 35% D capital structure, tax assumption 20%, labor cost $2.8m/yr, common ratios for other key costs. Elements specific to the particular plant design were specified separately to reflect the embedded cost tied to the particular 'product-process cost complex'.

Two particularly model elements should be noted: 1) corn stover as a feedstock in the 2G plant is substantially less expensive than corn in the 1G model, and 2) the assumed waiver subsidy value on cellulosic ethanol establishes a $3 per gallon floor on 2G plant ethanol selling prices. Both these elements should be considered as part-and-parcel of the agent-associated upside as the CEtOH agents can be considered to make these two aspects possible in the 2G operating plant.

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[2] Of note, Decision Tree Analysis (a Real Options analysis approach) can also be used to examine subsidy risks. Indeed, due to the gross uncertainty involved, many financial risk analysts recommend dealing with such risks in Decision Tree analysis supplementary to Monte Carlo analysis.

[3] CEtOH: Cellulosic Ethanol – 2G bioethanol produced from cellulosic (inedible plant structural) material

5.3. Simulation

The two most crucial variable factors, the feedstock and ethanol prices, were simulated via a Monte Carlo approach using Palisade @Risk. Corn for the 1G plant was based on an econometrically-derived volatility factor used to project future price variations (with a compounding variation effect as each year in the chain re-applied the volatility upon the previous year). Ethanol for the W1 plant similarly applied a successive econometric volatility to future forecasts.

For the 2G plant, feedstock costs were based upon an estimated starting spot price which then was projected to vary via the corn commodity price delta volatility, as above. Although the corn stover price was notably lower than the corn price, the tie to the corn price volatility was recognized (this can be broken-out as specifically corn stover historic volatility in future iterations). Concerning the ethanol price, a floor price of $3 per gallon was established (as per the waiver program) with a small chance for an upside when econometric simulation projected an ethanol price in excess of $3 per gallon.

5.4. Summary

By setting up each scenario to reflect common factors across the models and to distinguish those elements where the CEtOH agents result in added costs or savings, the resulting NPV traps upside unique to the use of the agent innovations.

6. RESULTS

6.1. NPV Analysis Results

The following static NPV values were derived for WACC = 15% (10 year / 10 year + Terminal Value)[4]:

1) **1G:** - $85 M / - $80 M TV
2) **2G:** - $10 M / +$50 M TV

The following static NPV values were derived for WACC = 20% (10 year / 10 year + Terminal Value):

1) **1G:** - $90 M / - $85 M TV
2) **2G:** - $10 M / - $35 M TV

[4] Note: figures have been abstracted / rounded from a generic model. Please contact SARK7 (sark7 @ sark7.com) if you are interested in more detailed analysis for your particular case.

6.2. Simulation Results

Figure 1 attached shows the variable NPV distribution outcomes for the 2G plant with 10 year scope and with 10 year + Terminal Value (TV) at WACC = 15%. *Figure 2* attached shows a comparison with the 1G plant.

Simulated items:

- Ethanol price (historical econometric basis)
- Feedstock price (historical econometric basis)
- Plant conversion productivity (simple range)
- Cost of enzymes (simple range)
- Cost of yeast (simple range)
- CAPEX (simple range)

6.3. Optimization: Pricing Guidance

An optimization routine was run on the Enzyme price for the 2G plant in order to determine the highest possible value whereby 'most likely' NPV was equal to '0'. For details see *Figures 5* and *6.*

The highest possible price for the Enzyme package in the 2G CEtOH scenario was:

2G w/TV: **$**0.XXX (@ WACC = 15%)
2G w/TV: **$**0.XXX (@ WACC = 20%)

6.4. Interpretation

The government subsidy credit in the model acts as a significant artificial hedge against a 'crush' scenario whereby the cost of feedstock outstrips the marginal cost of ethanol production compared to ethanol selling price. The CEtOH agent provides direct access to the 'trapped' value of the subsidy, allowing it to be priced into the product. However, in a competitive market, all upside beyond cost of production will ultimately face downside pricing pressure based on market competition. A struggle to lock-in customers early and to wrap the agents in value-added services will occur as the market matures.

As well, in a partnering scenario for deploying a packaged CEtOH solution set, there will be a natural struggle to assert value claims to the upside value of the CEtOH production capacity. More granular analysis on the relative proportional contribution to CEtOH production might be conducted in order to solidify claims to the value upside of the CEtOH capacity.

1G ethanol producers face a daunting dilemma, facing a 'crush' between high corn prices and volatile ethanol prices that show some likelihood of decaying in future scenarios. From the simulation, it appears that 1G ethanol production is a losing gambit. The 2G plant represent a logical 'flight to quality' scenario, bolstered and profitable due to low feedstock costs and the assurance of the waiver credit subsidy, which acts as an artificial hedge.

7. CONCLUSIONS

7.1. Integrated Analysis for Price Determination

The above has attempted to capture and recommend an approach for determining product pricing for a new technology within an evolving industry. Stochastic NPV analysis in a Project Finance context has been recommended as a method to extrapolate the value of an innovation so it can be cross-associated with an incumbent solution.

Utilizing a Project Finance approach allows for an explicit segmentation of risks across time. Utilizing NPV allows for a like-to-like comparison of the aggregate contributing value of a new technology-cum-product. Using stochastic (Monte Carlo) analysis allows for a cross-examination of relative risks and key sensitivities. When conducted in unison, solid guidance on the relative, risk-balanced potential market value of a new product can be extracted.

Three scenarios were run against each other as a demonstration of the principle in order to isolate agent-associated NPV value upside. An optimization approach allowed for pinpointing of a maximum price threshold.

For more information or to discuss running custom analysis for your 2G bioethanol product, please contact Scott Mongeau at SARK7 (sark7@sark7.com).

FIGURES HAVE BEEN REMOVED

TO DISCUSS CUSTOM ANLAYSIS, PLEASE CONTACT Scott Mongeau at SARK7 (www.sark7.com) sark7 @ sark7.com