Exploring New Business Opportunities through an Innovative Collaboration between Industry and Academia: Leveraging Advances in Optimization with a Market Model for Cap & Trade Emissions Compliance

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Air Products continuously seeks to improve its overall return on assets. Our core strengths in industrial gases and chemicals production are capital-intensive operations. To complement these activities, we began to develop value-added service offerings for our customers. We would leverage the skills and creativity of our intellectual assets to generate income, which requires a low capital investment.

Innovative technical solutions to support new business initiatives often require a synergistic collaboration of different skill sets within the company. We extend this leveraging effect by including academic leaders from business and technology in these collaborative efforts. This paper focuses on the successful internal and external technical collaborations that came together to support a new services offering. The new services offering ultimately did not gain sufficient market acceptance to create a sustainable business.

The Environmental Protection Agency (EPA) has classified the Houston-Galveston-Brazoria (HGB) area as an ozone non-attainment region for the one-hour ozone standard. The industry must reduce NO_x emissions by 80% during the 2003 to 2007 compliance period. The Texas Commission for Environmental Quality's (TCEQ) State Implementation Plan (SIP) to achieve compliance included a provision for Mass Emissions Cap & Trade (MECT). Air Products developed a service offering to reduce the industry's cost to achieve regulatory compliance using the mathematical programming expertise of its Computational Modeling Center (CMC) to exploit the benefits of the MECT program.

The determination of the lowest investment cost solution to achieve NO_x emission compliance involves discrete decisions. The discrete decisions are, for each point source, when to install and operate what control technology or combination of technologies over the compliance period. The installation time couples the investment decisions with the staged emissions reductions.

In mathematical programming, integer (yes/no, 0/1) variables represent discrete decisions, so we formulated the *NO_x Emissions Optimizer* as a Mixed-Integer Linear Programming (MILP) problem. The model contains over 200 companies, almost 3000 emission point-sources, and a two-tiered selection of control-technology alternatives. The number of potential solutions to an MILP problem grows exponentially with the number of integer variables. We could not solve this problem using conventional MILP solvers.

CMC's core expertise is not in the development of software applications and algorithms. Rather, it is in the proficient application of computational tools to improve our business and manufacturing processes. For this reason, the formation of venture companies spun off from leading academic research provides a successful technology-transfer mechanism from academia to industry. These spin-off companies provide us with access to the technologies that enable us to solve challenging problems, while alleviating us of the need to develop and, in particular, support and maintain a wide-variety of software solutions. To solve the MILP, we collaborated with Advanced Process Combinatorics (APC) Inc., located in the Purdue Technology Center, to utilize their expertise in Algorithm Engineering.

The *NO_x Emissions Optimizer* could now identify the least costly control-technology investment profile for each company working independently and for all companies working collaboratively under the MECT program. For the HGB area, Cap & Trade reduced the required investment cost by 16%.

We then developed the *NO_x Trading Model* to take these results and determine the amount traded and price of trades between companies based on the marginal cost increase to sellers and the marginal cost decrease to buyers. Although we could have represented the pairing of trading partners for each year using integer variables, we instead formulated it as a Mathematical Programming with Equilibrium Constraints (MPEC) problem, which we then solved as a Nonlinear Programming (NLP) problem using the *Generalized Algebraic Modeling System* (*GAMS*) modeling and optimization environment.

The business model had presupposed the establishment of a liquid trading market during the compliance period. As we began the commercialization-phase of the project, this did not occur. Our marketing lead suggested an options analysis to: (1) develop insurance policies for a wide variety of trading strategies, (2) provide market coverage without tying up a large amount of capital, and (3) offer such instruments to our customers to help initiate trades and generate market liquidity.

CMC comprises a diverse set of computational modeling skills, among them Chemical Engineers with a strong background in Statistical Sciences. The optimization models provided a surrogate of ideal market behavior to establish a spot price. The statisticians recognized that perturbations to the system result when certain companies are excluded from the trading process, establishing a crude estimate of the market volatility. They applied the Black-Scholes model to determine the option price and the sensitivity of the option price to fluctuations in volatility to a case study involving a small number of companies.

If we wanted to gain a better understanding of the volatility for the entire market, we would need to run these perturbations for the entire HGB area. To reduce the computational burden of performing many perturbed optimization runs, we could employ a systematic Design of Experiments (DOE) to achieve the most information content from each run. Not only would we vary the number of companies involved, but also the share of the savings between sellers and buyers. Using this methodology we could obtain a substantially better estimate of the spot price and the volatility of the spot price for contracts involving put and call options.

A major obstacle facing the establishment of a liquid trading market for the HGB is that companies are holding on to their perpetuity allowances due to uncertainty in the future regulatory environment. The EPA revoked the one-hour ozone SIP in June 2005. The TCEQ has to propose a new SIP for the more stringent eight-hour ozone standard by

November 2006 and adopt the final regulations by June 2007. The HGB industry will then have until 2010 to meet the new compliance standards.

We have illustrated how external and internal collaborations can be used to achieve a technical success by leveraging a diverse set of skills and by utilizing a research venture spin-off company for technology transfer from academia to industry. Air Products has elected not to pursue the services offering due to lack of market acceptance, due in part to changes and uncertainty in the regulatory environment.