

The GasDay Project at Marquette University: A Laboratory for Real-world Engineering and Business Experiences

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Abstract

This paper presents Marquette University's GasDay Project, a research activity that has been developing natural gas demand forecasting models since 1993. The project provides students with opportunities for research and employment, and serves as a major technology transfer center at Marquette by licensing software and forecasting models to energy companies across the United States. The project is part of the College of Engineering's Department of Electrical and Computer Engineering. Participants range from high-school age through graduate doctoral students; most are Marquette Engineering students, with several students coming from other disciplines including Mathematics, Computer Science, and Business Administration. These students produce an engineered, licensed product used by natural gas utilities throughout the United States to forecast over 20% of the United States daily natural gas demand.

Introduction

Collegiate engineering programs strive to prepare students to become successful engineers who are prepared to enter a workforce that badly needs them. A common experience for newly hired engineers leaving the classroom and lab behind is to bump into the reality that the best engineering decisions are not always the best business decisions, and vice-versa. Issues of cost, scalability, competitiveness, and others often force compromises into what might otherwise be the most elegant engineered solutions possible. An engineer new to the workplace might feel a bit disillusioned seeing how solutions are designed to meet multiple, often non-technical, objectives.

There's also the thorny matter of customers with their own wants and needs, their own business objectives, and their own varying levels of competency and available technical support – messy issues that don't often intrude into an engineer's education. Delivering and supporting engineered products into customers' hands to generate value for their businesses can require some skills that an engineer may not have encountered in college.

College engineering programs offer several enhancements beyond the classroom to help prepare engineering students for workplace realities. The most notable of these are co-operative (Co-op) engineering programs, and there are many other forms of internships, industry-sponsored research, and various other university-industry collaborations that help young engineers learn to apply their new skills at work. This paper describes a project that offers students the opportunity for paid engineering work right on campus, on a university-licensed software product.

GasDay Project Overview

Marquette University's GasDay Project licenses a natural gas demand software application to 24 natural gas utilities around the United States. On a typical day GasDay software installed at those utilities forecasts over 20% of the nation's natural gas demand. The models and software application are developed by undergraduate and graduate engineering students at Marquette, under the supervision of faculty members and a business manager.

The GasDay Project was begun in 1993 by Ronald Brown, Ph.D., as a research project funded by the Wisconsin Gas Company. Additional funding came from the Wisconsin Center for Demand Side Research, and then from the Gas Research Institute (GRI), a natural gas industry collaborative. That effort produced promising research results and the first forecasting models, which were put into use at the Wisconsin Gas Company in Milwaukee, WI (now part of We Energies). After a brief partnership with an outside firm, Marquette began licensing GasDay directly to natural gas utilities in 2001.

The GasDay Project is not the result of a strategic plan to enter into a retail software licensing business. Rather, it is the result of an unexpected end to a more typical university-industry technology transfer arrangement. Once the first GasDay model was in use at Wisconsin Gas Marquette University realized it had a licensable property. The university found a very large, international energy consulting business as a commercialization partner. The partnership was successful: GasDay forecasting tools were licensed by several utility companies. Unfortunately Marquette's partner ended up declaring bankruptcy due to problems in unrelated businesses. One result of that bankruptcy was that company's exit from the business that marketed GasDay.

That development left five natural gas utilities that had come to depend on GasDay without a solution. Each utility requested that Marquette establish a software license with them to assure uninterrupted service, which the university did, and Marquette GasDay was underway. As this licensing activity grew Brown staffed the GasDay Lab with graduate and undergraduate students who participated in his research and worked to expand and deliver GasDay.

Today Marquette University's GasDay Project is one of the largest research and technology transfer activities at Marquette. It remains within the Department of Electrical and Computer Engineering, part of Marquette University's College of Engineering. GasDay is self-funded from licensing revenue and research grants. The revenue generated by the project provides Marquette undergraduate and graduate students with opportunities for research, financial aid, and hourly employment. GasDay revenue also generates royalty income for Marquette.

GasDay Project Activities

The GasDay Project's activities provide the following contributions to Marquette:

Research Laboratory – the GasDay Project conducts ongoing research into energy demand and modeling techniques. This provides a rich and contemporary set of topics for graduate student research towards master's theses and doctoral dissertations. Research is funded by direct sponsorship of industrial partners and by GasDay product license fees. The results of

this research are disseminated as licensed software and research reports for our customers and as more traditional academic journal articles and conference presentations.

Educational Laboratory – the GasDay Lab regularly hosts course-affiliated student projects, providing students the opportunity to work directly with some of the largest energy companies in the United States. Many projects are from the College of Engineering’s senior design program, where a team of students work for a full academic year on a project of direct interest to a GasDay industrial sponsor. Other courses with students undertaking GasDay projects come from the College’s Engineering Management program and from the department of Mathematics, Statistics, and Computer Science. Approximately fifteen students participated in four GasDay Lab student projects over the last academic year.

Technology Transfer Center / Student Employment Site – Marquette University licenses GasDay software applications and mathematical forecasting models to energy companies. Marquette students participate in all aspects of this business, including software development and testing, data analysis and modeling, marketing, and customer support. This activity has the benefit of generating significant revenue used to fund excellent hourly work opportunities and graduate student support.

Over the last academic year the GasDay Project provided the following student financial support:

- assistantships for five graduate research assistants in the College of Engineering and one from the Department of Mathematics, Statistics, and Computer Science
- hourly employment for one graduate student and thirteen undergraduate students from the College of Engineering
- hourly employment for one high school student participating in Marquette Engineering Outreach programs, who plans to study engineering in college

Industrial Outreach Center – Over the course of a typical year, the GasDay Project interacts with approximately thirty companies working in energy or related industries. We conduct on-site visits and teleconferences, and we host several companies who visit Marquette University. GasDay also helps organize the Gas Forecasters Forum, an industry conference held each fall as part of the Southern Gas Association’s Fall Leadership Conference.

Licensable GasDay Technologies

GasDay licensable technologies are the result of the commercialization of GasDay’s laboratory research. Students are involved in every step of this process – from participating in the research, to implementation and test of new features, to final delivery and customer support activities.

Marquette University licensed GasDay products include:

GasDay - Marquette University’s flagship energy forecasting technology. The GasDay family of technologies includes GasHour, GasMonth, the Additional Weather Inputs model enhancement, and other application enhancements and services.

Measurement Scene Investigator (MSI) – a data analysis tool used by utilities to detect errors in the reporting of natural gas flow to large industrial and commercial customers.

Heating Oil Consumption Forecaster (HOC) – a GasDay tool licensed to heating oil companies to aid in delivery planning. This tool can be generalized to support any business involved in non-continuous delivery of energy.

The GasDay Annual Business Cycle

There is an annual cycle to the business of GasDay that makes it well-suited for student participation. Not surprisingly, this cycle is based on the timing of the heating season in North America. Natural gas utilities spend the summer and early fall each year preparing for the upcoming heating season. So does GasDay. The fall is the busiest time of year at GasDay as students prepare software deliveries for our gas utility customers.

Research activity that leads to new model development ideas is ongoing, but each fall GasDay prepares a significant software release timed to coincide with the onset of the heating season. Early each spring, faculty and students jointly determine which model improvements to implement in GasDay product software, and work begins on that. At the same time, a separate team of students develops a work plan for software implementation of the features and improvements for the fall release. The combined teams set milestone dates for intermittent Alpha and Beta releases, software testing, integration testing, and mock customer deliveries for practice. All this work culminates in deliveries of new GasDay configurations sent out to customers throughout the fall season.

Every GasDay delivery is a custom configuration specific to a utility's natural gas distribution system. Most utilities are comprised of multiple energy distribution regions, or *operating areas*. GasDay students train custom models for each individual operating region and then merge those models with the current release of GasDay application software. Every integrated configuration is tested and packaged for installation at the customer site.

GasDay Model Improvements

The subject of most graduate students' research is related to improvements to the GasDay forecasting models, or the various treatments of the data used to train those models. Some example topics include:

- investigations into methods to build forecasting models for non-stationary systems
- an investigation into improved techniques to disaggregate monthly data into daily using correlated data (temperatures)
- improved detection and treatment of outliers in natural gas daily or hourly flow time series data
- ensemble techniques for combining multiple forecasts
- consider goodness-of-fit measures on various types of unusual days or derived from business costs
- model frequencies of unusual weather events

- exploitation of high-density weather measurements and forecasts

Ideas developed in student research that provide measurable, consistent improvements to GasDay demand forecasts are implemented each year in the GasDay product. This requires two implementations: a reference implementation in MATLAB that demonstrates the improvement across a wide variety of data sets; and a production implementation in the GasDay C++ model library that is shipped with the GasDay product. During final product testing, before release to manufacturing, the GasDay library results are compared to results generated by the MATLAB reference implementation to an accuracy of 10^{-9} across a large number of data sets.

In this way, a student in a two-year Master's degree program might see an idea from conception through to product implementation and delivery to a customer during her graduate school career.

GasDay Software Product Development

GasDay's software development team is led by a recent graduate of Marquette's Biocomputing program, who chose to join GasDay as a full-time employee upon graduating. The decision to hire a staff member to supervise this team helped to overcome problems caused by the frequent turnover of staff. The software development team tends to be staffed by undergraduate students majoring in Computer Engineering, Electrical Engineering, Computer Science, or Biocomputing.

GasDay software development is typical of many software product activities, pursuing two agendas:

- Software defect repair is year-around work, performed by all members of the team, old and new. Defects reported by customers or in-house testers are logged into an automated issue management system used by the team lead to manage the workflow of each assignment from investigation through to final test and resolution.
- New product / feature development is concentrated in spring and summer, though some form of product enhancement is always taking place. This work is driven by requirements captured by all GasDay team members using an issue management system and product development wiki.

GasDay's software development processes introduce students to many of the tools of the professional programmer and mandates use of many of the practices students encounter in their *Software Engineering* coursework. Elements of the software development teams practice include:

- Agile software development techniques, including frequent deliveries of working software, pair programming, team review, and test-driven development.
- Frequent collaboration with GasDay customers to improve application usability or to develop new feature ideas. GasDay is very fortunate to have a set of customers who agree to install Beta-version software to evaluate and test new features as they take shape.
- Tools for requirements management, issue management, and automated testing and test reporting.
- Software configuration management tools for change control and managed releases.

GasDay student software engineers get to participate in early-stage idea development through to feature implementation and release to customers. Participation in GasDay software development reinforces the importance of a disciplined and collaborative team approach and gives students an early opportunity to embrace techniques being taught in the classroom.

GasDay Data and Manufacturing Team

The *Data and Manufacturing* team are the GasDay members who manage and execute GasDay customer deliveries and follow up with customer support. Member of this team range from GasDay's very newest students to some of the project's most experienced graduate students.

At the start of the fall delivery season, sub-teams teams are assembled and assigned a set of customers with individual GasDay delivery dates spread out over several weeks of the fall. Each of these teams is responsible for receiving and managing the data that customers send to the lab for new model training, using the following process:

1. A student contacts the customer to establish delivery dates. Customers already have an expectation that new models and software will be delivered to them. The customer uses an automated tool to transmit data to the GasDay Lab.
2. A student generates a "data suspects report" that is reviewed with GasDay faculty, and used to work with the customer to correct errors.
3. Once data is cleaned a student will submit a job to GasDay's compute cluster for model training. This processing typically requires one to three days, depending on the number of customer operating areas and length of historical time series data.
4. Students merge the newly generated models with the current GasDay software release.
5. The new GasDay configuration is tested by multiple student team members, according to test processes documented in the project wiki.
6. A Microsoft Windows installer is created and tested on a computer that matches the customer's versions of Windows and Microsoft Office. GasDay IT Support students are tasked with making sure each Windows system configuration is available for this testing.
7. A GasDay configuration that has passed all stages of testing is uploaded to a secure FTP site for customer retrieval.
8. Students from that customer's manufacturing team will contact the customer to alert them to the installer's availability, and assist with installation and any other issues or questions.

Each team is led by a graduate student who usually knows the customer they are working for. Other members are newer graduate students learning the processes and younger undergraduate students who are learning the basics of how the GasDay Project works. Everyone participates, and much of the work is done in pairs to facilitate learning and catching errors.

The senior GasDay team members who lead these data and manufacturing activities serve as project managers and subject matter experts. Because of the rapid turnover of GasDay members to co-op employment and graduation, the structure of these teams serve to continually train up newer members into more complex roles. Another benefit of pairing undergraduate and graduate students as collaborators is that it provides undergraduate students a view of what it means to be a graduate student and to consider that as an option for themselves.

IT Support and Business Operations

Two other areas providing interesting work experiences are supporting the significant computing environment of the GasDay Project and participating in the business operations of the project.

Marquette University provides excellent IT support and basic management of our computer systems; however, the GasDay Project compute environment is customized enough that the project requires at least one student, and often two, to maintain all equipment and software. A very common task is to equip a new or refurbished computer system with a standard GasDay software configuration so that any student on any of the teams can log onto that computer and find all the tools they need. Interspersed with this are typical occasional failures of power supplies, hard drives, and other components. Students on the GasDay IT support team are able to replace failed parts, secure rebuilt systems, restore missing data, and reconnect to GasDay network resources.

GasDay also tries to maintain at least one student on staff to assist with the business of GasDay. Typical tasks for this role include generating license renewal notices, assisting in proposal development, developing marketing materials, and small project management. This role is often filled by a student from Marquette's College of Business Administration.

New Student Development

There is a tremendous learning curve when joining GasDay. A new team member must absorb a great deal of information about natural gas as a fuel, energy industry concepts, GasDay's role in that industry, and countless details about the data, methods, and results that are central to the product's function.

The most typical entry point for a new team member is to join the data and manufacturing team. Almost immediately, a new team member is able to put their basic MATLAB skills to work processing customer data or providing assistance in one of the many ongoing research activities. Students who have the best experience at GasDay are the ones willing to dig into an assignment and get comfortable working under the direction of a graduate student or faculty member.

The GasDay Project has several weekly structured meetings that new team members are expected to attend. This participation helps accelerate members' contributions to the project.

- The weekly *LDC Meeting* is a review of each GasDay licensee and any open issues or pending work they may have. It is at this meeting that teams are formed and assigned to each issue, or, during the fall delivery season, to the building and configuration of each utility's deliverable. New team members quickly become acquainted with each of the GasDay licensees and the particularities of their model or application.
- A weekly *Manufacturing and Development* meeting is a setting for topics related to new process ideas, improvement of existing processes, overall scheduling and planning, and special project development and discussion. This meeting has become a very valuable forum for students to identify obstacles or shortcomings in how they perform their jobs, and for the team to collaborate on ideas for improvements.

- *GasDay Camp* is an intensive series of hands-on sessions where new team members are led by a faculty and graduate students through the GasDay customer experience, from downloading and installing a new GasDay configuration, to running daily forecasts, and diagnosing common issues. This is where new team members learn about natural gas industry basics and the business motivations that lead a customer to value a product like GasDay.

Early in the project's history it would take at least a semester, and sometimes two, for a new team member to find a way to contribute and become productive. Over the years it has become obvious that the best mentors to new team members are the existing team of graduate students, who take the lead in organizing and overseeing most student orientation activities. Now a new student joining the project at the start of the fall semester becomes a key contributor to some of the GasDay configurations tested, built, and delivered later that same semester.

GasDay Project Challenges

GasDay's "academic" staff is its students and two faculty members. Administrative staff includes a business manager, a software team leader, and an administrative assistant. The majority of project workers are students, whom it is our mission to graduate to a career outside Marquette. This poses some significant obstacles to ongoing operations in a business developing a complex, engineered product customized for customers across the United States.

A typical student will start working for the GasDay Project at the start of their Marquette career: when they enter either as a freshman undergraduate or new graduate student. Undergraduate students have less background and experience to bring to the project, but are often able to spend four years working on the team. Graduate students usually will have a richer background to draw from, but most are master's degree students, and will only have a two year career. Everyone starts out at about the same level of ability, with some classroom knowledge, but little work experience. This represents GasDay's two significant staffing challenges: inexperience and frequent turnover.

As in most workplaces the best method to manage this challenge has been to grow strong contributors into leadership roles where they are able to mentor and develop newer team members. The less we try to force assumptions upon the team about who fits where based solely on age or class year, the more each student rises to their own level of competence and leadership. It is not unusual to see a junior-year undergraduate student teaching and directing the work of a new graduate student, or a second-year master's student teaching manufacturing team processes to new freshman at GasDay Camp session. As much as possible every GasDay role is described on the project wiki as a pair or team activity, so that there is always the opportunity for new team members to observe advanced GasDay activities at the side of a more experienced student.

A typical university is not an ideal home for a software product business. While many elements of a successful business are present, it takes careful management and planning to combine them into something sustainable. Some elements of a software business that were foreign to typical university business operations include price quotations and negotiations, invoicing processes, individual licensing of custom products, and participation in industry trade shows, to name only

a few. Fortunately the various Marquette University departments involved with each of these items have been very supportive and flexible, and have invested the time to develop repeatable processes that lead to predictable results.

Conclusion

This paper has described Marquette University's GasDay Project, a working software product business that provides undergraduate and graduate students the opportunity to apply their classroom learning in a real, functioning business environment. Some of the benefits to students are:

- Hands-on learning in a business setting with real-world consequences for successes and failures
- Direct contact with customers and other industrial partners, and opportunities to teach them how to use GasDay and learn from them and their experiences with the product
- Experience with project management and the importance of working in a setting with competing priorities that must be met with a fixed set of resources
- Knowledge of how research is conducted, and the process to take it from the laboratory to the marketplace
- Immediately relevant career skills
- Financial support in the form of hourly salaries or research assistantships

Students leave the project with genuine work experience, letters of reference, and the experience of having participated in the larger setting of the College of Engineering beyond the classroom.

References

1. Blair, B.F., Millea, M., & Hammer, J. (2004). The impact of cooperative education on academic performance and compensation of engineering majors. *Journal of Engineering Education*, 93(4), 333–338.
2. Brown, R.H., Kharouf, P., Matin, I., & , L.P. (1996). Development of artificial neural network models to predict daily gas consumption. *American Gas Association Forecasting Review*, 5, 1-22.
3. De Lange, G. (2000). The identification of the most important non-technical skills required by entry level engineering students when they assume employment. *Journal of Cooperative Education*, 35(2), 21-32.

Biographical Information

THOMAS QUINN, M.S. is the business and customer relationship director for Marquette University's GasDay Project. Mr. Quinn manages GasDay sales and licensing activities. He has also worked to bring new GasDay Project research to market as licensable technologies for the University.

RONALD BROWN, Ph.D. is an Associate Professor of Electrical Engineering and the GasDay Project's founder and chief scientist. In his GasDay work Dr. Brown has supervised the work of over 100 graduate and undergraduate students. Dr. Brown is a regular invited speaker at energy industry meetings and conferences.

GEORGE CORLISS, Ph.D. is a Professor of Computer Engineering and contributing senior scientist with the GasDay Project. Dr. Corliss has adapted GasDay model technology to two new applications under license to energy companies. He is an active participant in the lab's research and industrial partnerships.