The Role of Process Engineering in Reducing Greenhouse Gas Emissions

Paper # 636 Presented 6/26/08 Session ES-4b(2)
Air & Waste Management Association's Annual Conference and Exhibition

Julia Vetromile
Tetra Tech EM, Inc, 135 Main Street, Suite 1800, San Francisco, CA 94105

Michele Grossman
Tetra Tech EM, Inc, 135 Main Street, Suite 1800, San Francisco, CA 94105

ABSTRACT

This paper explores the role of onsite process engineering staff to identify potential opportunities and implement greenhouse gas (GHG) reductions projects. Based on site interviews, this paper explores the concept that onsite engineering staff, combined with effective corporate management, are key factors in reducing GHG emissions reductions in onsite energy use. The development of GHG reduction projects is explained as a variant of classic process engineering projects. Specific examples of government and private organizations where onsite staff are implementing projects that reduce GHG emissions are provided. These examples demonstrate that the combination of motivated on-site engineering staff and effective management support can achieve significant reductions in energy consumption. Finally, the difficulty of achieving significant GHG reduction projects without process engineering or management support is described.

INTRODUCTION

This paper discusses why some organizations are more likely to achieve greenhouse gas (GHG) emission reductions than others. Several organizations have developed definitions for GHG emissions reduction projects, including the World Resources Institute and the World Business Council on Sustainable Development (WRI/WBCSD)[1]. The process engineer is uniquely suited to develop and implement GHG reduction projects, using the classic process engineering approach. The job of the classic process engineer is to find inherent opportunities to improve the product, reduce raw material use (including energy), minimize waste and pollution, and save money. Looked at this way, a GHG emissions reduction project is a well-documented process engineering project.

Modern industrial process plants like breweries or waste water treatment plants are built using processes that are available at the time of the plant's design and construction. Over the lifetime of the facility, the plant owners have many opportunities to modernize and update the process, the equipment, and the operation. Regulations, laws, taxes and other legal and corporate requirements may also require operational changes. Companies that focus on the continual process improvements that benefit the plant operations and their customers are in an excellent position to develop projects that reduce GHG emissions.

The current political and business climate increases the probability that regulatory, voluntary or business requirements will necessitate GHG reduction projects. Many states are implementing or planning to implement new laws and incentive programs to reduce GHG emissions. Therefore it is essential that business understand key mechanisms for success in developing GHG reduction projects.

In the course of performing GHG emissions inventories and verifications, the authors had the opportunity to work with a range of organizations, both public and private. Typically, the organizations were members of a voluntary program such as the California Climate Action Registry or EPA Climate Leaders. These organizations were highly motivated to reduce GHG emissions. Yet clearly some entities had more success than others in reducing GHG. Common elements in the success of organizations to reduce GHG were the presence of an onsite champion to reduce energy and therefore GHG emissions and support by active and engaged management.

COMPARISON OF PROCESS ENGINEERING WITH GREENHOUSE GAS REDUCTION PROJECTS

What exactly is process engineering, and how does it relate to GHG reduction projects? The key aspect explored in this paper, the role of process engineering in re-inventing existing processes, relates to GHG reduction projects. Dictionary definitions of process engineering focus only on the concept of manufacturing.[2] Businesses define process engineering more in line with industry practice:

- The design of a series of unit operations, actions, or activities that produce a desired product or end result.[3]

- Assessment and development of procedures and responsibilities in conjunction with personnel and technology capabilities with the intent to take advantage of inherent opportunities.[4]

This paper focuses on the “intent to take advantage of inherent opportunities” for greenhouse gas reductions from existing facilities and processes.

Basic Steps of Process Engineering Projects

Both engineering and financial goals must be met for successful process engineering. Process engineering in manufacturing includes several steps.[5] The following are the basic steps for process engineering projects, modified to illuminate the aspects relevant to GHG reduction projects:

1. Inception: Determine a need
2. Baseline: Conduct an initial mass and energy balance
3. Initial analysis: Preliminary evaluation of economics and market

4. Process development: Develop the data needed for design
5. Modified baseline: Estimate the mass and energy balance employing the new process
6. Funding: Estimate the project metrics such as ROI and payback period
7. Implementation: Detailed design, procurement, and construction
8. Start-up: Integration into operations
9. Evaluation: Conduct a mass and energy balance following the process change

The steps are very similar to the requirements for GHG reduction projects under currently available protocols. Definitions of GHG inventory and GHG reduction projects are necessary before we go further.

Definition of GHG Emissions Inventory and Reduction Projects

A GHG inventory[6] is a list of the amount of Kyoto GHGs emitted from sources under control of a particular entity. The Kyoto GHGs are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

A GHG reduction project is one that removes GHGs from the atmosphere or prevents them from being released. GHGs can be removed from the atmosphere in a number of ways, such sequestering CO_2 in the earth, oceans, or forests. Examples of preventing GHGs from being released into the atmosphere are preventing deforestation, eliminating venting of methane at landfills, and capturing methane from ruminants.

Protocols have been developed for a number of different kinds of GHG reduction projects. The Kyoto Protocol[7] established the Clean Development Mechanism and Joint Implementation procedures for countries that ratified Kyoto and want to reduce their GHG emissions by supporting a GHG reduction project in a developing country; the WRI/WBCSD[8] have a protocol for grid-connected electricity projects; and the California Climate Action Registry[9] has developed protocols for forestry, landfill, and livestock projects.

A GHG emissions inventory results in a baseline or datum against which future inventories and reductions can be measured. The inventory is necessary before any real reduction in GHGs can be assessed. During the process of determining where emissions are generated and how they are measured or calculated, concepts for possible GHG emissions reductions projects may be engendered.

Process Engineering and GHG Reduction Projects Steps

Based on the nine steps described above, this section of the paper will compare how a GHG project is like a typical process engineering project.

The first step is to identify a need for changes in the existing facility. In the author's experience, projects are initiated in order to make improvements—in costs, product yield, labor relations, regulatory compliance, safety, efficiency, risk management, or other business factors. For a GHG reduction project, the need for improvement is to reduce GHG emissions.

The second step for a process engineering project, to understand and measure the baseline situation, is the basic requirement for beginning a project. How does the existing system work? What are the product requirements for the particular unit operation?   Would using a different raw material, better instrumentation, new process equipment or other changes provide desired results and/or cost savings?

For a GHG reduction project, the approach is essentially same.[1] Assess the current operations; where are GHG emissions highest? Where can actions be taken that are likely to be cost-effective?

The mass and energy balance of the baseline case provides a baseline for determining the effect of the proposed process change. In the case of a GHG project, the baseline is a GHG emissions inventory around the portion of the process where the change will occur. An emissions inventory looks at the GHG emitted from the process units. For example, a plant that requires drying as part of their process could want to determine the advantage of a different type of dryer. In that case, the mass and energy balance of the existing drying operation is needed before determining how effective a change would be.

Step three, initial analysis of the economics and market is the evaluation of where changes could be technically and profitably made. After identifying a problem or opportunity and determining the baseline, the process engineer looks for potential solutions available with current or emerging technology. In this conceptual design phase, engineers brainstorm possible ideas for improvements. Examples of GHG project types include using improved equipment, new processes, better instrumentation and process control, different energy sources such as cogeneration or solar, and redesigning products to use less GHG.

Step four, developing the process and the data required for detailed design. The step may involve literature review, interviewing peers and technical experts, calculations, bench-scale and pilot scale testing, and customer acceptance evaluation. For example, substitution of a raw material which embodies less GHG may require bench scale and pilot scale tests to determine feasibility, cost, and changes in product parameters. The final product may require market-place evaluations to determine acceptability to the customer.

Once the revised process is developed, the engineer can then estimate the new mass and energy balance, and estimate the savings in GHG (step five). For significant proposed product changes, steps 4 and 5 are likely to be iterative. Although GHG protocols do not require steps 4 and 5 explicitly, as a practical matter these are likely to be necessary steps that business managers require.

Process engineering projects typically are funded based on an evaluation of return on investment and payback period for the capitol investment (step six). The GHG project protocols don't require such an evaluation. For a GHG project, the tons of CO_2 equivalents saved compared to the cost is a useful metric for businesses to determine the most appropriate projects to fund. GHG projects that also show a good return on investment will be attractive to businesses.

Once a project is determined to be worth funding, the detailed design can be developed and the project constructed or implemented (step seven). After a startup phase (step eight) where the operating parameters will be finalized, the project will be integrated into plant operations.

Now that the project is part of operations, it is possible to evaluate its effectiveness with a new mass and energy balance (step 9). For a GHG project, a new GHG inventory must be conducted and compared with the baseline inventory to estimate the reduction.[1]

The Advantages of Onsite Process Engineers

For GHG and process engineering projects, the inception step is the critical one—determining a need. In the author's experience, onsite staff who are looking at the current operations every day can ask what could be done better, cheaper, more consistently, with less waste, less GHG, less pollution, higher yield, safer to employees, more attractively to the customer. Do we need to use so much energy? How could we use less?

In modern manufacturing plants, the need for staff to run the equipment has been reduced by advances in robotics, instrumentation and controls. Yet there remains a business need for onsite process engineers who continually evaluate the onsite process and find the opportunities for reductions in GHG, cost, waste, and energy.

Offsite specialized staff, including consultants, are effective at providing information and state-of-the-art experience. They may provide key information to the onsite staff suggesting what kinds of processes could be effective at various types of operations. For example, offsite corporate environmental staff who are knowledgeable in sustainable practices can facilitate change by providing information and support for changes at the plant level. Consultants can provide case histories and design know-how of what has worked at similar facilities.

Business management support is critical to the implementation of process engineering and GHG projects. Goals and metrics that management sets can encourage or require process engineering changes at the facility level. Company management can develop special challenge goals, encouraging energy efficiency. EPA Climate Leaders [10] program encourages corporations to develop key goals. For example, Anheuser-Busch, a member of this program, developed a corporate challenge to reduce their energy use by 5%.[11] New regulations, taxes, or corporate agreements on voluntary processes may also require changes at the facility level.

Ultimately, regardless of the amount of offsite support, it is the onsite staff who must achieve the project requirements. For a GHG project, it will be the onsite staff that manages the reductions in energy use or the process change that results in less GHG emissions.

Case Studies

Several examples of how onsite staff are employing process engineering to reduce GHG are provided through recent work in third-party verification of GHG emission inventories. From wastewater treatment plants to Navy bases, staff that are highly motivated and empowered to make changes are reducing GHG.

Union Sanitary District

According to the Department of Energy[12], wastewater treatment plants are typically one of top users of energy for a municipality. Wastewater treatment generate anaerobic digester gas (ADG), which is primarily methane, in the biological decomposition of sewage biosolids. Because ADG contains at least 20% carbon dioxide, it has lower heating value that natural gas, but can be combusted in combined heat and power cogeneration systems. The heat can be used for heating the biosolids and maintaining required temperatures, to make water or steam and to cool or dehumidify buildings. Electricity generated can be used to run mechanical systems.

Union Sanitary District (USD) in Union City, operates a wastewater treatment facility that treats an average of 27 million gallons of water a day.[13] California has been operating their ADG cogeneration system since 2005. This system is saving USD an estimated $40,000/month.[12] It provides about 25% of their electricity and essentially all of their process heat. [14]

USD won the *Collection System of the Year Award* from the California Water Environment Association in 2005. Interestingly, USD has also won this award in 1987, 1990, and 1999; no other wastewater district has been honored so consistently.[15] What's different about Union Sanitary?

USD has an unusual approach to management. Supervisors are given the title of Coach. According to the Oakland Tribune[16], the credit for the award goes to the team of Union Sanitary District employees called the "Collections Work Group" -- including mechanics, custodians, office assistants, collection system workers and supervisors.

One of the coaches is their process engineering manager, James Chen, whose job includes making process upgrades. These upgrades save the District money, reduce GHG and save energy while providing effective service to their district. Mr. Chen and his staff continue to look for ways to reduce energy (and thus GHG) and save money for their constituents. Ongoing projects include plans for additional low emission vehicles and plans for additional energy generation from the ADG.[17] Union Sanitary joined the California Climate Action Registry, submitting their 2006 inventory. They've added

GHG reduction to their goals. With continued management support and onsite engineering staff who are empowered to develop process upgrades, USD is on a path to continued GHG reductions.

Anheuser-Busch Brewery

Champions at both the plant level and the management level are critical to achieving process improvements. An example of a process improvement champion is Bill Bennett, Resident Engineer at the Anheuser-Busch Fairfield brewery. During a review of Anheuser-Busch's greenhouse gas emissions inventory, Mr. Bennett described several specific projects undertaken to reduce the energy used and to minimize wastes hauled offsite[18] He cited replacing inefficient lighting and reviewing operations to develop and implement cost-effective equipment updates. Anheuser-Busch also found an application for the spent grain generated from the brewing process. Instead of generating a waste product that required treatment and disposal, the spent grain is sold for cattle feed. Heat recovery processes at the brewery have reduced the energy required at the plant. Mr. Bennett stated that the Fairfield Anheuser-Busch brewery has reduced its energy consumption by 10% in the last five years.[19] This example demonstrates how the combination of corporate sponsorship for energy efficiency discussed above and the associated GHG reduction with an onsite process engineering champion enables significant GHG reduction.

Waste Management

In another example, the active involvement of onsite staff to monitor and control existing processes minimizes the GHG emitted. GHG reduction projects that are installed must be operated so as to achieve the desired results over the long term. Waste Management operates a biomass power plant in Shasta, California, which receives, stores, and combusts large volumes of organic materials such as wood chips, railroad ties, and nut shells. The senior engineer, John Neal, constantly monitored and evaluated the operation of the combustion to minimize GHG emissions.[20] The presence of motivated onsite staff to consistently evaluate, as well as operate, process equipment ensures that the GHG reductions will continue.

U.S.Navy

Onsite managers and engineers whose mission is to reduce energy will be able to achieve significant GHG reductions. The Department of Defense is required under executive order 13423 to reduce energy use by 30% by 2015, to reduce water use by 16% by 2015 and to obtain 25% of its electricity from renewable energy sources by 2025.[21] With military bases with energy bills in the millions of dollars, DOD has found it cost-effective to employ a full time Resource Efficiency Manager from a consulting firm.[22] With the twin drivers of an executive order and the need to reduce energy costs, Resource Efficiency Managers have been able to reduce overall energy and water use and increase The Department of Defense's renewable energy portfolio.

Resource Efficiency Managers have managed initiatives ranging from no-cost measures to major capital projects to meet the energy and water reduction goals for military bases. A list of the projects implemented at one Navy base[22] in a single year shows how a wide range of conservation measures results in constant reductions in energy demands:

- Added 57 KW to its existing 750 KW photovoltaic carport
- Built the Navy's first building-integrated solar roof, a 51 KW photovoltaic system integrated into a new roof membrane
- Supported a Navy pilot project to reduce pierside energy costs aboard active Naval vessels; this project returned over $4 million in savings to the Fleet with a return on investment of over 10:1
- Installed demand limiting direct digital controls for an HVAC system
- Tracked down and corrected millions of gallons a year in water leaks
- Performed chiller plant audits and evaluated economics for retrofits
- Implemented new programming sequences to disable secondary computer room air conditioners when the primary unit is able to maintain setpoints.

The energy savings that are generated by the onsite manager typically pay for the consulting firm cost with a 200% return on investment. The projects range from detailed capital projects to consistent process improvement of existing systems. The program tracks key categories including industrial facility efficiency improvements, combined heating/cooling and power plants, onsite electrical generation, reductions in electrical load and reductions in petroleum consumption, water usage, basic energy management practices, building energy monitors and the energy awareness program. Some bases have employed Resource Efficiency Managers for more than eight years, and the savings continue.[23] Again, the combination of onsite engineering staff and effective management support creates the possibility for significant and ongoing reductions in GHG.

Barriers to GHG Reduction

This paper postulates that sufficient onsite process engineering staff supported by management goals and funding is key to generating GHG reduction projects. The barriers to GHG reduction projects can be identified using a similar thought process.

The lack of motivation, capability, or authority of plant staff to implement process improvement and GHG projects can be a significant barrier. The literary legend Virginia Woolf was once asked to provide an essay on Women and Fiction. She responded that what mattered for the creation of fiction was to have sufficient time and a place to write; the ability of women to create fiction depended on having a "room of one's own."[24] It's no different for GHG reduction projects. Capable staff must have enough time, budget, and management support to identify and implement the projects that can result in GHG reductions.

Staff with duties that require their full attention may lack the energy to evaluate new ideas. Plant operation is demanding; where facilities only have staff for operations innovation is more difficult. In some cases, the staff are not trained as scientists and engineers and may not have the capability to implement GHG projects. In contrast, the presence of capable staff who were given project time to develop GHG projects was a key factor in saving energy and reducing GHG emissions at the USD, Navy and Anheuser-Busch case studies.

A lack of capital for investment for GHG reduction projects can be a barrier. Corporate ROI goals that allow reasonable time for development of a process are required to maximize innovation. Many more projects can be implemented with a 5 year ROI than a 2 or 3 year ROI. The inability to get management attention for GHG or process improvement projects can be a barrier. [25] Savings may be significant, but the value is below the radar screen of top executives who are concerned with other corporate goals. In contrast, at DOD sites with an executive order to achieve reductions, the onsite staff was empowered to meet savings goals.

Another barrier is lack of rewards for developing GHG reduction and process engineering projects. Organizations that reward staff who reduce GHG by salary increases, promotions, and/or appreciation are more likely to implement GHG reduction projects. DOD established annual awards for meeting department goals. The Resource Efficiency Management program won the Secretary of the Navy Energy Award 2 out of the last 4 years. In 2006, the Resource Efficiency Management program won the Federal Energy and Water Management Award. The Resource Efficiency Management program was supported by managers who knew awards were available.

Loss aversion may also derail GHG reduction projects. Companies and managers unwilling to risk making a mistake will avoid taking advantage of process improvement opportunities.[26] Plant obsolescence increases fastest where process improvements stop.

In the course of performing and verifying GHG inventories for the California Climate Action Registry, the authors had the opportunity to compare and contrast organizations that were more or less successful in reducing GHG. All the companies were pro-active because they were developing GHG inventories. But in some organizations, it was clear that implementing major changes would be difficult. Where the inventory was seen entirely as the purview of the environmental departments, there was the least chance of success. The environmental department alone does not have sufficient authority or process and production know-how to institute significant changes. Where the corporation had empowered the plant staff as well as the environmental departments, significant changes were possible.

SUMMARY

In conclusion, GHG projects, like traditional process engineering projects, are most able to be completed successfully when management empowers process engineers. This paper has demonstrated through several examples that onsite site staff who are motivated can make impressive gains in GHG reductions. When capable, motivated engineers are available to assess plant operations, generate ideas, and acquire funding for projects that meet reasonable financial goals, GHG reductions projects will multiply.

REFERENCES:

1. World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI). *Greenhouse Gas Protocol: The GHG Protocol for Project Accounting* December 2005. http://www.ghgprotocol.org/standards/project-protocol

2. MSN Encarta, Definition of Process Engineering, http://encarta.msn.com/encnet/refpages/search.aspx?q=process+engineering (accessed February 2008).

3. Creative Engineers Inc, Definition of Process Engineering, P.O. Box 206 , Phoenix, MD 21131. http://www.creativeengineers.com/chemical-processing-glossary.html. (accessed February 2008).

4. Advanced Information Concepts Inc, Definition of Process Engineering, 7827 Calla Donna Place S.W.Calgary, Alberta: http://www.icreb.com/compprof.html (accessed February 2008).

5. Plant Design and Economics for Chemical Engineers, Peters and Timmerhaus, McGraw Hill. 1968.

6. California Climate Action Registry, General Reporting Protocol, Version 2.2, page 4. March 2007.

7. United Nations, *Kyoto Protocol to the United Nations Framework Convention on Climate Change* 1998. http://unfccc.int/resource/docs/convkp/kpeng.pdf

8. World Business Council for Sustainable Development World Resources Institute.*The Greenhouse Gas Protocol; Guidelines for Grid-Connected Electricity Projects.* http://www.ghgprotocol.org/files/electricity_final.pdf

9. California Climate Action Registry, *Forest Project Protocol.* September 2007*; Landfill Project Protocol; Livestock Manure Management Protocol*. November 2007.

10. EPA Climate Leaders program: http://www.epa.gov/stateply/partners/index.html (accessed February 2008).

11. Bamberger, Audrey. Personal communication with Julia Vetromile on February 24, 2008.

12. Combined Heat and Power Subcontractors Coordination Review Meeting, Oak Ridge National Laboratory, April 14, 2005. http://www.eere.energy.gov/de/pdfs/conf-05_chp_subcontractor_rev/chprev05uschpa.pdf (accessed February 2008).

13. Union Sanitary District Facts. http://www.unionsanitary.com/mission.htm). (accessed February 2008).

14. Jim Chen, Union Sanitary District. Personal communication with Julia Vetromile on October 11, 2007.

15. California Water Environment Association 2006. http://www.cwea.org/mlr_member_awards_past_ca.shtml (accessed February 2008).

16. Chris De Benedetti, Oakland Tribune, "*Union Sanitary District flush with kudos*" Feb 8, 2006

17. Jim Chen, Union Sanitary District. Personal communication with Julia Vetromile on February 28, 2008.

18. Bill Bennett, Personal communication with Julia Vetromile on November 8, 2007.

19. Kevin Courtney, Napa Valley Register, "*Global Warming the Topic for County Leaders*" November 20, 2007. http://www.napavalleyregister.com/articles/2007/11/20/news/local/iq_4222967.txt

20. John Neal. Waste Management Senior Engineer. Personal communication with Barbara Toole O'Neil on October 31, 2007.

21. Federal Register, "*Executive Order 13423—Strengthening Federal Environmental, Energy, and Transportation Management*." January 26, 2007.

22. U.S. Navy. 2007 Annual Energy Report for Naval Base Coronado.

23. Jon Duke, Personal communication with Julia Vetromile on February 27, 2008.

24. Virginia Woolf. "A Room of One's Own." 1929.

25. Douglas C. White. "*Improve Your Project's Prospects*." Chemical Processing magazine. 2004 (http://www.chemicalprocessing.com/articles/2004/144.html)

26. David Goldstein. *Saving Energy, Growing Jobs: How Environmental Protection Promotes Economic Growth, Competition, Profitability and Innovation.* Bay Tree Publishing. 2007.