High Performance Industrial Energy Conservation: A Case Study

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I describe and analyze a very high performing energy conservation program at a major U.S. chemical manufacturer and compare it to two other virtually identical but much less successful programs in the same company. All three consisted of competitions in which engineers submitted projects for evaluation by a program committee.

I found that the success of the high-performing program came from its ability to manage two competing demands. On one hand, it was structured to maximize the ease with which information and skills relevant for energy conservation could be brought together. On the other hand, however, such a design required people and other resources needed by a number of other functional managers (e.g. safety, waste reduction, affirmative action, training, United Way, and the blood drive). Furthermore, energy was relatively cheap. Therefore, the second demand was to create a program which would attract the necessary resources. To be acceptable, the energy manager had to avoid conflicts and offer more than energy conservation, or even energy conservation with a high return on investment. Rather, the success of the program lay in its ability to offer line management and participants joint gains between their own objectives and energy conservation objectives.

Introduction

I will describe and analyze a highly successful energy conservation program of one U.S. division of a major chemical manufacturer, FLECSOCO (a pseudonym). By understanding how a high performing program works, we will gain insight into the problems faced by low performing programs. I will briefly compare it to two other similar, but less successful programs within the same company.

I will argue that the managers who design these programs must manage two competing demands. On one hand, because energy conservation decision making is a difficult information processing problem, particular aspects of the energy conservation problem are best solved by particular individuals with particular skill sets and access to particular information sources. Housekeeping problems are best solved by the operators; simple substitutions of existing technology for new technology by consultants; process design changes by the production engineers; and research and development conundrums by specialists. Therefore, the first demand is to construct programs which utilize the groups most relevant to the problems specific to that site.

On the other hand, program designers rarely have free or guaranteed access to the target people. Most of the time they compete with a number of other functional managers who also have "top management commitment" (e.g. safety, waste reduction, affirmative action, training, united way, and the blood drive). Furthermore, the target people have very limited time, since most of it is devoted to producing chemicals. Therefore, the second demand is to design programs which will provide the people and resources needed for effective waste reduction in the face of competition for those resources.

Because energy is relatively cheap, the second demand dominates. In order to get the necessary resources, the energy manager had to do two things. First, he had to avoid conflicts with other actors' interests. Second, he had to offer more than energy conservation, or even energy conservation with a high return on investment. Rather, his success depended on his ability to offer line management and participants joint gains between their own objectives and energy conservation objectives. The political and structural obstacles which define the constraints and create the possibilities for joint gains varied across time and across the sites. At Marbletown, the program designer could develop a program which targeted the most effective group on the site, the junior engineers.[1] At other sites, slight variations in capital allocation and technology mix meant that while these people could be targeted, the energy conservation manager could not bring them in permanently.

Data Collection

Data for this paper were collected in the context of a larger study of pollution reduction programs. I collected most of the data through interviews of 50-90 minutes duration. Five interviews were longer, lasting two to three hours. Key interviewees were interviewed several times. Company employees were interviewed at corporate headquarters in September 1989 (eight interviews), various plants: Marbletown in May 1990 (eleven), Schisttown in June 1990 (sixteen), Hornfelstown in October 1990 during a visit to discuss safety management (one) and at various seminars, conferences and other opportunities (four). Four interviews were carried out by telephone, and many were followed up that way.[2] Key interviews and sections of interviews were transcribed. In addition, I searched the trade literature, company publications, and examined the records of an "ethical investment" firm for information about the company, its behavior in general, and its energy/environment/ethical behavior in particular. Finally, I discussed my work and exchanged literature with a journalist who writes about the company. Early drafts were reviewed by key people in two divisions and corporate headquarters. This proved to be a vital source of new data, insights, and clarification. Differences were discussed and changes were made at the discretion of the author.

Marbletown Energy Conservation

The Marbletown site, located in the Southeastern U.S. is one of the largest chemical facilities in Marblestate. Its twenty-four processes manufacture mainly commodity chemicals, but also some specialty chemicals, power supply, an incinerator and a biological oxidation plant. It employs about 3200 people including about 1000 maintenance contractors. It is non-union, and has been since opening in 1958. Within each plant, as in other divisions, there are three or four hierarchical levels of line engineers under one of the twenty superintendents. Each superintendent reports to one of five production managers who, along with people like the human resources manager, are known as major managers. These all report to the facility general manager.

The program began when the division's long term fuel gas supply contract expired, so the long-run marginal cost of gas rose significantly. When division management asked a senior engineer to investigate ways of reducing energy usage, he developed a disarmingly simple program, based on another in the Gneiss division. Engineers were invited to submit designs for cost effective energy conservation projects of up to $200,000 capital value and saving at least $10,000 annually to a competition committee comprising senior engineers, some superintendents, engineering managers, and a representative from the capital planning economic evaluation area. The projects had to offer a rate of return on investment (R.O.I.) exceeding 100%.[3] The submissions did not have to be formal but they had to provide data and sketches which would substantiate the energy savings the engineers claimed they would make. The competition committee reviewed the submissions, declared some of them "winners", and provided a ranked list of projects to division management. The review consisted of an oral presentation by the person submitting the project, a more detailed financial analysis and a check of the engineering details to ensure the works would operate as claimed. In return for their effort, the submitters of winning projects received a plaque at an awards ceremony and the opportunity to oversee the detailed design and construction of the project. They did not (and still do not) receive any financial reward.

The winning projects were placed into a pool with other projects submitted to the division for small capital allocations. Division management would then allocate the capital money to the plants, and has always included money for the winning projects. The money would then be invested, at the discretion of the major manager overseeing the plant, either in the project or for some other need.

The program has been extremely successful and phenomenally profitable (table 1). The program has run since 1982, with annual investments rising from $1,700,000 in the first year through to $22 MM in 1990, and dropping to $17 MM in 1991. (Note: These figures include projects > $2 MM and cross-subsidized waste reduction projects which are excluded from Table 1.) Average annual return on investment has varied from 77% to 340%, and is generally around 150%.

The success of the program has amazed everyone in the corporation, both in terms of its longevity and effectiveness. Everyone thought the division would run out of energy conservation projects after the usual program life of two or three years. On the contrary, the staff have been able to find more and more projects each year. Interviewees now believe that there is almost an infinite number of projects out there.

The competition has changed a little since its inception. First, the hurdle R.O.I. dropped to 30% with the price of energy.[4] Second, the categories of projects have expanded to include all small capital projects (i.e. up to $2 MM instead of $200 000), large capital projects (more than $2 MM), and expensed projects. Expensed projects and large capital projects are not funded from the small capital pool, however. Finally, the categories of projects have

Table 1. Marbletown Program Historical Performance

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Number of projects	27	32	38	59	60	90	94	64	115	108	109
Cost ($MM)	1.70	2.20	4.00	7.10	7.10	10.60	9.30	7.50	13.10	8.60	6.40
Fuel gas savings ($MM/yr)	2.97	7.65	6.90	7.53	7.14	5.53	4.17	3.05	5.11	2.11	5.17
Total savings ($MM/yr)	3.06	7.63	8.35	10.22	8.29	11.50	18.02	37.06	17.57	27.65	20.28
Average ROI (%)	173%	340%	208%	124%	106%	97%	182%	470%	122%	309%	305%

Source: Company materials
Note: Excludes projects >$2 MM and waste reduction projects funded through internal cross subsidies

been increased to include yield improvements, maintenance cost reduction projects, waste reduction projects (in 1986) and a few small capital expansions. Waste reduction projects have a different investment criterion which allows projects to be cross-subsidized. Projects include redesigned refrigeration systems, preheating fluids, reconfigured distillation columns, and removal of bottlenecks in processes.

To understand how this program works, we need to answer two questions. (1) Why does this particular set of organizational arrangements lead to high performance? (2) Why does the program survive, given (a) programs within the company usually survive two to three years, including an attempt to replicate this program (b) energy prices have been falling throughout the program's life, and (c) there are many other demands on engineers and operators' time? The next two sections address these questions in turn. To answer the first question, we should consider energy conservation as an information processing problem. To answer the second, we need to consider this program as one of many competing for scarce corporate resources.

Energy Conservation as an Information Processing Problem

Energy conservation decision making is a difficult information processing problem. Because people can process only limited amounts of information (Simon 1976) and participants must search for the information they need to make decisions (March & Simon 1958), factors which shape the availability of different types of information--such as the context within which decision making occurs--will prejudice search, leading to local rationality which may be quite different from the global rationality we expect (Cyert & March 1963).

Cebon (1990; 1992) elaborated on these ideas. He observed that three distinct classes of solution-specific information had to be brought together for that solution to be adopted. The first class, technical information, generally defines the characteristics of the technology to be implemented. It includes such things as its specification, performance, and price. This information generally comes from sources outside the organization. The second class, contextual information, describes the location in which the technology will be situated and hence the precise interfaces the technology must satisfy to fit into that location[5] (i.e. the requirements for the technical system, with all its idiosyncrasies; similarly for the people directly affected). This information is generally embedded in the workplace. The third class, connected information, deals with aspects of the technology and its implementation relevant to other functions. A particular technological change may affect worker safety, satisfaction, or skills, for example. This information comes from groups within the organization functionally or geographically removed from the site of the technology (Lawrence & Lorsch 1967). Cebon found that in the relatively mechanistic (Burns & Stalker 1961) universities he studied, changes in structure which increased access to one class of information generally reduced access to the others. Therefore, energy management decisions appeared highly structure-dependent and solutions requiring high technical and contextual information were selected only in extraordinary circumstances, such as when the senior university administration was devoting a lot of attention to energy conservation.

Different types of energy conserving technological changes require different mixes of these types of information. Housekeeping changes require very little technical information but a lot of contextual information. As a general rule, the amount and complexity of the technical information required increases markedly as changes become more capital intensive. The person or group identifying and appraising the problem needs a conceptual understanding of the relationships between larger and larger parts of the plant. For example, to insulate some pipework, you need only understand the temperature of the pipe, the physical layout, and the way the space around the pipes is used. To eliminate an entire refrigeration step, you need to understand the whole production process as well as a slew of alternatives to refrigeration. Also, possible technical solutions and ideas may come from increasingly diverse parts of the environment. Ideas about valves can come from any chemical plant. Ideas about homeomorphic sets of steps may have to come from plants half way around the world. Valves come from valve suppliers, but special equipment may need to be designed or purchased from obscure sources. Retrofit projects can generally ignore context since they tend to replace a technology with an improved version of itself. For R&D, contextual information is probably of limited use once the problem has been defined. The requirements for connected information are probably independent of project type.

Informational Aspects of the Marbletown Program

Given this review of the informational requirements for energy conservation, we can see that the Marbletown program was positioned in exactly the right place in FLECSOCO's communication system to maximize energy conservation effectiveness. It utilized engineers being assisted by operators.[6] When the engineers are the focus of the program, they will use the contextual information given to them by the operators and which they gather themselves to enhance their understanding of the technical system as a whole. Given a much more abstract set of skills, an understanding of a larger spatial extent of the plant, and much better access to FLECSOCO's information processing network, the engineers can solve problems better. For example, a number of engineers I interviewed discussed the ease with which they could call or e-mail people they hardly knew half way across the world to discuss particular technical issues (c.f. Granovetter 1973).[7] In addition, the company has produced a manual which summarizes each technically distinct project which has been carried out. Therefore, because the junior engineers have access to the right mix of information, and because the projects are just the right size to excite them, a political climate which enables them to do the work and motivates them to want to do it will lead to the generation of many projects.

Power and Motivation in Energy Conservation Decision Making

Being able to identify the best people to conserve energy is not sufficient. Energy conservation decision making requires the bringing together of resources from throughout the organization and hence the bringing on-side of the parties which control each resource. Two aspects of this are noteworthy. First, and most obviously, energy managers tend to be much less powerful than production managers but need significant resources controlled by production management. In this case, the key resources are the production technology itself, which must be changed, the production workers, and the production engineers. Subsequently, production managers allowed 25% of their annual capital allocation to come through the competition. Simultaneously, managers from many other equally important, yet low-powered functional specialties--e.g. quality, safety, automation, training--are vying for the same production resources.

Second, and more subtly, large organizations tend to have trouble allocating small amounts of capital efficiently (see Ross (1986) for example). While some waste reduction investments are large, most tend to be small, so we expect to see difficulties. Compounding this, many corporations try to ensure capital is used efficiently by deliberately allocating applicants less capital than is requested. Energy conservation projects, being optional and proposed by low powered managers, are likely to be eliminated after such rationing.

Therefore, there is no reason, *a priori*, that the manager should have been able to implement the program. In fact, managers who have attempted to implement similar programs at other sites in the company have failed and managers in other companies frequently tell the program organizer that they could never implement such a program in their company. Hence, we must ask why the program succeeded. In the following section, we will discuss why everyone who was involved in the program: the participants, the superintendents, and other managers on the site, supported its initiation and continuance.

Explaining Success at Marbletown

Initial Support from Plant Superintendents. In the early 1980s, the Marbletown plant superintendents were feeling two cost pressures. First, in 1981-82 the company, having suffered badly in the market as a result of the oil price shocks, decided to diversify into specialty chemicals.

This meant limited capital funds for the commodity processes which predominate at the site. Second, because energy prices were high and commodity processes are energy intensive, the inefficiency of some processes at Marbletown was a concern. An important way the superintendents of these processes could get money would be through the divisional small capital funds (which are allocated to the site rather than the business). The best way they could compete for these funds was on the basis of return on investment. Therefore, a group of superintendents were strong early supporters. They used the competition to fund projects which allowed them to do things they wanted to do, but which incidentally gave them energy conservation gains. For example, one superintendent used the competition to increase the capacity of his plant by 30% while justifying the projects on the basis of energy savings.[8] As additional benefits, the competition projects improved process efficiency at low capacity, made that process easier to run, and increased enormously the production range in which the plant was profitable as they saw when the market for the product picked up in the late 1980s.

Support from Training Managers. In 1980, the company saw its chief resource as its junior engineers rather than the operators.[9] After a couple of years, the competition organizer realized that in addition to providing challenging and interesting work, it provided them with an excellent training opportunity. As he put it to me:

> "There's lots of training involved in the projects. The engineers take a project to completion. They use decision making tools. They learn the process of getting ideas, collecting data, evaluating projects, making presentations, doing detail design and supervising construction."[10]

He went on to add:

> "Get people making decisions early in their career. The important thing is that decision making is not guessing. There is a technique. People need to get a feeling for the number of facts they need to gather before making a decision. ... As you move on, the mistakes become more expensive."

Over time, engineers found that by involving the operators they supervised in the process, they could generate more projects. Therefore, the competition also enhanced their management skills.

Support from the Junior Engineers. While training may be a virtue, it doesn't explain why the junior engineers would participate enthusiastically. To understand this, we must consider its role in FLECSOCO's internal labor market.

The plant superintendents have managed to enact a shared belief, which may or may not be true, that excellence in the competition is vital for engineers who want to be in the running for promotion. The argument is quite simple. First, the competition enables the engineers to stand out from the other engineers and be seen by the superintendents of other processes. There is a very public awards ceremony and winners get a paragraph in the division newsletter. Only one or two other activities in the division offer this sort of prominence. As one interviewee described it:

> And, what he successfully did is he convinced plant superintendents and engineers that if you did not participate in that program; if you did not turn (in) a WRFP (Waste Reduction For Performance) or energy project, and if you were not at the big meeting every year to receive an award and all the major managers were sitting there and you got to walk up the aisle, and the general manager handed you your award and shook your hand. If you weren't one of those guys, you weren't going to get very far in FLECSOCO.

Second, if you can do well in the competition, you have a set of skills which the company values. You can work with data, work with and enthuse the people you supervise, make decisions, write capital requests, oversee detail design, and supervise construction. Therefore, the claim has very high face validity to all involved.

Unless everyone believes that participation leads to promotion, the whole system fails. Consider the counter example of the safety and environment superintendents, one of the routes to a superintendent's job. This position was created to try and alleviate some of the pressure on the superintendents as they attempt to meet safety, environmental, quality, and productivity objectives simultaneously. It was also seen as a training exercise. The hope was that these people, when they became plant superintendents, would have a strong safety or environmental focus.[11] Each safety or environmental superintendent oversees four or five plants. One interviewee described what happened after the position was created:

> We titled the job "superintendent" to try to impress upon the people in the division that it was a serious job. We even came out with letters to say that we had put our best people in those jobs.

Unfortunately, the best people weren't put into the jobs. He continued that

> (this meant that the superstars) go straight to running the plant (as production supervisors). This is an important point, because if we had successfully sold the job as being an intermediate step to plant superintendent, we would have had more of our superstars ask for the job.... (We couldn't sell this idea because) in FLECSOCO, we will never promise a guy his next job. We could pick a safety superintendent, and we could insinuate that he will be the next plant superintendent, but we will never promise that. ... And, unless it actually works out that way, the superstars perceive very quickly that it is all false.

Over time, the job has become more routinized and so it has become less of a position for super-stars. However, in its more routine form, it could still be seen as an important job for ascending junior professionals.[12]

Continued Support from the Superintendents. I see three reasons why the superintendents supported the continuation of the contest. First, while it is possible to fund any worthwhile project at FLECSOCO, that money is not necessarily easy to obtain. Superintendents always seem to have an incentive to get more money. Therefore, once the competition was in existence and using up 25% of the site's small capital, they had a big incentive to participate. Second, the superintendents are in "friendly" competition with each other. Their plants are constantly being compared to other plants on the site and other plants making the same product.[13] Plants are evaluated regularly on the basis of a scorecard, a set of a measures of plant performance. Since the initial placement of plants on various dimensions on the scorecard is a function of the basic technology, the relative rankings of the plants at a particular point in time is not terribly important. However, changes in those rankings over time are. Therefore, superintendents are constantly trying to improve the performance of their plants. Finally, superintendents derive status from their ability to promote junior members of the company. If superintendents believe the competition provides the route to success and they want their engineers to be successful then they will support the competition.

Avoiding Conflicts with Other Programs and Interests.

While the Marbletown program provides joint gains to superintendents, engineers, training, and, from the point of view of energy conservation, waste reduction and maintenance, it is important to realize that it also avoids a number of important conflicts.

Avoiding Conflicts over Capital. The first conflict is over capital. As noted above, the program is unusual in that the money is allocated after the projects are selected rather than from within a fixed budget as we might expect. I asked the organizer why:

> "The competition started in Gneiss... The organizer made a mistake by trying to commit capital. It meant that every year he had to fight for it. I avoided any control over capital. I didn't want to compete with the major managers. I'd lose. ... The managers are under a lot of pressure to fund the projects anyway."

I asked what that pressure was. The organizer explained that competition process creates expectations from a large number of parties, particularly the engineers who have come up with the designs, to spend the money on the project even though the superintendents don't have to. The problem with the Gneiss approach, as someone else explained, is that in a company where both the program managers and the division managers change jobs about every three years, it would not be long before either a program manager or a general manager would arrive who was not interested in either making a pitch for funds or providing them.

Avoiding Conflicts over Time and Rewards for Line Employees. It is for the same reason that no financial awards are made by the competition to the people who come up with the designs. As the organizer explained:

> "There are no financial rewards since it competes with the line. A program cannot compete with the organization. That is, WRFP has no bureaucracy and no budget."

Instead, they simply give out a plaque and a symbolic promise of financial rewards later on.

A related cause of concern might be that the contest takes up too much of engineers' time. An engineer I interviewed explained that it didn't. He came up with projects by thinking about waste reduction and energy conservation opportunities as he walked around the plant. The contest took little time; just keeping notes, collecting relevant data, and brief write-ups of proposals.

Avoiding Conflicts with Other Functional Groups. A final conflict was pointed out to me when I discussed the program with the organizer of a similar energy conservation program at another site. He pointed out that programs like this could cause antagonism because they encouraged managers to under-allocate their annual monies to some areas in the hope of picking up money for those areas through the competition. The Marbletown contest managed to avoid this conflict by opening itself up to a large number of functions (maintenance, waste reduction, yield improvements) in addition to energy conservation.

In summary then, we can see that by accident and by design, the energy manager at the facility has managed to do two things. First, he has targeted the group of people who are most competent to find innovative solutions. Second, and more interestingly, he has managed to construct the program in such a way that all of the parties whose active support is needed--the engineers themselves and the plant superintendents in particular--wanted the program to begin and continue, irrespective of its energy conservation performance. By the same token, the program is non-threatening to (and in fact is advantageous to) managers of other programs and functional areas such as waste reduction, maintenance, and capital allocation.

The above discussion implies that the whole process of program design is highly political. There aren't enough resources to do what everyone wants, and people don't have equal access to those resources. Therefore, some allocative mechanism has to be developed in the face of competing interests. However, there is no overt conflict over those resources. This is because the program designers are very senior employees of the company who have worked as plant superintendents for many years. Therefore, what may appear to an outsider as conflict over resources, and is experienced as a conflict in other organizations, is seen by them as a set of constraints within which they must operate.

The Schisttown and Hornfels Competitions

To round out the discussion, we will consider two other programs, in the Schist and Hornfels divisions. The Hornfels program aimed at energy conservation and was modelled on the same Gneiss program as the Marbletown program. The Schisttown program was an attempt to implement the Marbletown program, without the waste reduction component, as a part of the "continuous improvement" effort. Although, at the surface, these programs are virtually identical to the Marbletown program--both involve engineers submitting competitive designs for consideration by a committee--slight differences undermined support from key actors.

The Schisttown program, which started in 1987, ran for two years. Both years they designated about $8 MM in projects as winners for an average R.O.I. in excess of 100%. The organizing committee decided to scrap the program in the third year. The differences at Schisttown revolve around the way capital is allocated. Each division is given money to allocate as small capital for projects of less than $2 MM. Two equity-based principles are commonly used to allocate capital to the individual plants; the replacement value of the capital and the amount allocated in the previous year. So plants might be allocated 4% of their replacement capital, for example. At Marbletown, Gneiss, and Hornfels, the competition added a third principle. Instead of allocating all the small capital on equity-based criteria, a portion of it was put into competition and therefore allocated on the basis of efficiency. At Schisttown, the contest organizers couldn't persuade the general manager to do this. Instead, he insisted that, irrespective of the competition outcomes, all the small capital would be allocated on the prior equity basis. In so doing, he immediately eliminated most of the incentive the superintendents might have for supporting the competition. Instead of the engineers' submissions being seen as a source of extra capital, they were seen as a time sink. Once sufficient projects had been identified to use the annual budget wisely, there was no point in wasting time on fancy proposals. As the organizer explained:

> "At the superintendent level, they didn't want to see guys writing these up and submitting them. They would rather see their guys working on the projects themselves."

The Hornfels program started in 1983 and lasted about five years. It was scrapped in 1988 when the number and quality of programs submitted started to decline. While in the third and fourth years they had about forty worthwhile projects, the fifth year yielded only thirty. While the organizer suggested to me that there was less energy conservation potential there, I find that implausible given the Hornfels division is several times the size of the Marbletown division. This is also inconsistent with Japanese experience.[14] Given that the organizer may not have wanted the program to take off to the same extent as Marbletown, we cannot say the program was a failure.

Notwithstanding, given the program died as soon as energy prices dropped, we can say it was not terribly well institutionalized.

As I see it, three aspects of the program design prejudiced its success. First, as with the Gneiss program, funds were allocated before the winners were picked. As noted above, the organizer at Marbletown saw this as a liability at Gneiss. Presumably it was a liability here also and it would have been much harder to fund once energy prices started to fall. Second, the Hornfels site is huge--over 150 plants--and there isn't the same dominance by commodity plants as in Marbletown. For this reason the organizer had concentrated on the energy intensive plants and had advised the specialty plants to not bother participating in the competition. I asked the superintendent of one specialty plant about engineers in that plant participating in a subsequent version of the competition set up for waste reduction. I was told that this was discouraged because the big savings are in the commodity plants and so there is no point in competing with them.[15] Third, with such a huge site and such an enormous staff, it may be hard to create the belief that the program enhances someone's chances for promotion. That is, the facility is so large that everyone is anonymous and differences in technology which can normally be compensated for rise up as obstacles.

A corporate reviewer suggested fourth reason. Another difference between the two programs was that Hornfels accepted proposals four times yearly instead of once. In such a situation, the system of competition deadlines makes it relatively easy for people to defer indefinitely putting effort into writing submissions.[16]

Discussion and Conclusion

More than anything, I think this paper shows how incredibly difficult it is to bring about a high performing energy conservation program. The root of the problem is that our organizations are designed to use a given set of technologies to produce a product. Energy conservation requires an organization which makes part of its production the constant re-evaluation and reproduction of its technology. With each iteration, the technology is improved to be more consonant with the changing institutional environment.

However, our organizations are not set up well to do this. We have looked here at an exceptional case; an organization with a long history of process innovation and a deep commitment to safety. Its approach to safety requires behaviors which are ideally suited to energy conservation. That is, it achieves safety through innovation rather than threat of sanctions, and the process of finding those innovations is virtually the same as that for energy conservation. Still, however, slight contextual changes and slight variations in program design mean the difference between success and failure. Contextual changes include the difference in facility size, slight differences in approach from one manager to another, or differences in time so that operators are the center of the firm's attention rather than the production engineers. Minor design differences include an emphasis on a few plants on a site rather than all and slightly different approaches to capital allocation.

This suggests some fairly sobering things to me. First, I think we can subdivide energy conservation innovations into two groups; those which diffuse and those which don't. The innovations which diffuse are essentially commodity-like retrofit technologies; lights, motors, computer controls, and the like. As we have discovered, these technologies tend to diffuse very slowly. However, with the aid of price shocks, varying policies to make the technology differentially attractive to different contexts, and progressive improvements in technology to make it less context-dependent, diffusion can be sped up (see also Rogers 1983).

However, for the big savings, the picture isn't so rosy. The big savings require the people who are intimately familiar with the technology to take the time to critically re-evaluate it with energy in mind. It doesn't matter whether it is the product engineer working out that a screen-saver should also turn off the hard disk and the fan (or that laser printers should have a stand-by mode which puts less heat across the drum and turns off the fan) or a chemical engineer taking a fresh look at a chemical process. For these types of innovations, it seems that our organizations are particularly fragile.

Furthermore, in the case here, I have looked at a very high performing firm. Most of the time, we are looking for energy conservation in organizations which don't make their money by being the very best at process innovation. As we move to less and less innovative organizations, the prospects for innovative energy conservation become dimmer.

Notwithstanding, there are two silver linings. First, once someone has seen a way of fixing a particular problem, the second person need only hear of the solution rather than find and solve the problem. That is, every innovation becomes, to some extent, diffusible. Second, the extent to which a manager must actively create joint gains depends on the norms of the organization in which she operates. If a firm, as a matter of course, has a successful quality program with large amounts of employee participation, the manager might be able to simply tap into that program. In so doing, she capitalizes on the organization's limited reflexive capacity and encourages its development. Similarly, if employees are better trained, programs will be easier to implement. While these are not traditionally considered the domains of energy policy, they may be the most valuable places to start.

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Endnotes

1. FLECSOCO's five manufacturing divisions in the U.S. are located in five different regions. The four discussed in this manuscript will be referred to by the pseudonyms of Marble, Schist, Gneiss, and Hornfels.

2. Telephone interviewees were given an opportunity to review the notes from the interview since it wasn't taped.

3. Only operating (non-capital) savings were to be considered.

4. The high R.O.I. criterion was used because savings were in short run energy acquisitions. The price of fuel was high in 1980, but there was no guarantee that it would stay high. As the price of fuel dropped, the hurdle R.O.I. dropped to 30%. A project yielding 100% R.O.I. in 1981 would have yielded about 30% R.O.I. in 1988.

5. Contextual information differs from tacit information (that based in skill), in that contextual information can be communicated if the person wanting the information knows what question to ask.

6. We can appreciate the importance of this structuring approach by contrasting it to two alternative approaches. One would be to focus on the operators, as is advocated by many people in the "quality movement". Given the discussion above, we expect this to yield projects which lack technical substance. The second, as is the case with most utility programs, would be to use outsiders (e.g. corporate engineering staffs or consultants). In this case, we expect people to have insufficient contextual understanding to find the sources of wastage and hence an emphasis on retrofits and standardized solutions to problems rather on the redesign of wasteful processes.

7. A number of other corporate artifacts show the emphasis on communications. The corridors in corporate headquarters are wide enough for people to walk eight abreast. This undoubtedly facilitates conversation. Similarly, when the company designed its new main research laboratory in the 1930's, the floor plan was organized to force everyone past everyone else's desk regularly. Finally, one of the plant sites was building a process similar to one located in Germany. The operators of the German facility participated actively, at several stages, in the design review for the new process.

8. All R.O.I. calculations assumed that he was running the plant at the capacity demanded by the market at that time.

9. For a capital intensive company, a key source of competitive advantage lies in its ability to design efficient processes and construct them quickly and well. Therefore, engineers who are good at design and construction are a vital resource.

10. Quotations delimited with quote marks (") are reconstructed from interview notes. They are not verbatim quotations.

11. I am not suggesting here that these positions have been a complete failure. I understand they have, in general, been very successful. The point is that they have failed to achieve one of their goals, to provide environmental or safety sensitivity training for the best upcoming managers.

12. We can only speculate as to why it was easier to create the shared belief in one case than the other, but there are two plausible explanations. First, it is very easy to see if safety superintendents are being promoted but it is much harder to work out whether competition winners are. Many more people win in the competition and it is always assumed to be a relatively marginal thing. Second, there may be a professional/cultural reason. Knowing how to manage

safety is something the company asserts is important but knowing how to design, build, and manage things is something any junior engineer knows is important.

13. For example, FLECSOCO has seventeen plants globally making one common plastic.

14. Kornbluh et al (1984) cite the example of the Kyowa Petrochemical Plant where 31% of small group suggestions related to energy conservation. The average Japanese firm implements over 900 suggestions per year.

15. This interviewee was selected by the safety staff as an excellent safety manager. It may well be that the managers in Marbletown who are overly concerned about safety also discourage their engineers from worrying about waste. However, I don't know since other interviewees were selected by the environmental staff.

16. Note that in both cases, the program organizer stayed in the division after the program was terminated. Therefore, we can eliminate the hypothesis that these programs died because they weren't around long enough to be institutionalized.

References

Burns, T. and Stalker, G. M. 1961. *The Management of Innovation*. London: Tavistock Publications.

Cebon, P. B. 1990. *The Missing Link: Organizational Behavior as a key element in Energy/Environment Regulation and University Energy Management*. Masters thesis, M.I.T., Cambridge Ma.

Cebon, P. B. 1992. "Twixt cup and lip: Organizational behavior, technical prediction, and conservation practice." *Energy Policy*, September, (Forthcoming).

Cyert, R. M. and March, J. G. 1963. *A Behavioral Theory of the Firm*. Englewood Cliffs NJ: Prentice Hall.

Granovetter, M. S. 1973. "The Strength of Weak Ties." *American Journal of Sociology* 78(6):1360-1380.

Kornbluh, H. *et al;* "Worker participation in energy and natural resources conservation." Final report of the project: *Employee participation in conservation: The U.S. and Japanese experience.* Mimeo, University of Michigan Institute of Labor and Industrial Relations, December 1984.

Lawrence, P. R. and Lorsch, J. W. 1967. *Organization and Environment: Managing Differentiation and Integration*. Boston: Graduate School of Business Administration, Harvard University.

March, J. G. and H. Simon. 1958. *Organizations*, New York: John Wiley and Sons.

Rogers, E.M. 1983. *Diffusion of Innovations* 3rd Ed. New York: Free Press.

Ross, M. Winter 1986. "Capital Budgeting Practices of Twelve Large Manufacturers." *Financial Management* pp. 15-22.

Simon, H. A. 1976. *Administrative Behavior: A Study of the Decision-making Process in Administrative Organization.*