Application of the Engineering Method: Key to Successful Energy Project Proposals

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ABSTRACT

The engineering method as it applies to energy engineering project proposal was discussed. Real world case studies were presented as examples to show how the steps in the engineering method promote technical energy and cost savings solutions. The engineering method also serves to provide reports that build a trusting relationship between the plant and the auditor through structured thinking, discussing, concluding, and communicating.

INTRODUCTION

Too many times, energy managers and executives have been presented with energy proposals that have been qualitatively prepared. And too many times have these project proposals been dismissed on the ground of not being convincing enough (or that-can't-be true syndrome). Those proposals may be of fine quality and may result in excellent products. But they impress fewer people everyday. On the other extreme, although not as often, one may have received proposals that may be of dissertation quality. They, too, turn people off on the appearance of being unrealistic, or the all-too-familiar wise saying, "theoretically sound but…"

Managing energy utilization and environmental degradation is a delicate balancing act. On the competing front of efforts against inefficiency and wastefulness, we cannot afford failing to reach the end goal of the balance beam for two reasons: (1) the financial savings for the company, and (2) the environmental protection or enhancement for the generations to come, all at the same time.

Some examples of qualitative audit findings are (all savings are on an annual basis):

- Control the operation of the janitorial vacuum motor by static pressure to save $19,000
- Repair steam leakage in the boiler room to save $97,000
- Get rid of screen savers on PCs to save $7,600
- Run the standby compressor during off-hours to save $11,000
- Provide occupancy sensors for lighting control to save $34,000

The legitimacy of the savings is not the issue here. In fact, they are real numbers. But if these are all the energy managers or decision-makers are given, chances for them to be funded, and funded quickly, are struggling at best or, at worst, rejected. Energy projects are capital investments and, for that reason, resultant savings must be quantifiable, verifiable, and made easy to understand.

This article presents the application of the engineering method in the energy project proposal process which, in the experience of the author, can be the cornerstone for quick payback and profitable projects.

The intrinsic and idea-cultivating steps of the engineering process can foster an environment for structured proposal—one that is backed up with alternatives, quantified analyses, constructability, testability, and verifiability.

THE ENGINEERING METHOD

As scientists use the scientific method to investigate naturally occurring phenomena, engineers use the engineering method in conducting engineering studies. The engineering method consists of the following steps [1, 2, 3]:

1. What is the problem? (or **the problem statement**)
2. What are the relevant constraints and criteria to be adhered to? (or **the research and investigation**)
3. How is the problem to be solved? (or **the solutions**)—alternative solutions considered—recommended solution

4. What is the analysis of the recommended solution? (or **the analysis**)
5. What are construction and testing anticipated to be? (or **the design, construction and testing**)
6. What is the final evaluation of the solution, taking into account the constraints and criteria? (or **the final evaluation**)
7. How are the results to be communicated? (or **the communication**)

Those are the popular steps of the engineering method. How would this method be applied to an energy audit proposal? To highlight the differences, the following energy project proposals will be presented separately—one using the qualitative approach and the other the quantitative (engineering method) approach.

First, the Qualitative Approach

As a result of the plant visit, the following three energy projects are proposed to capture a total saving of $358,000 annually.

Proposal No. 1: The centra-vac system was observed to run continuously even when the load is low during off-hours and weekends. We recommend the plant switch to the smaller standby compressor during low load period. Energy cost saving is estimated to be $11,000 a year.

Proposal No. 2: The compressed-air supply valve of the air-operated condensate return pump was found in a stuck-open position. This renders the system nonfunctional. We recommend the plant repair and return the unit to the designed condition. Energy cost saving is estimated to be $6,000 a year.

Proposal No. 3: We observed a plume of live steam being vented continuously from the operation of the thermal oxidizer unit. We recommend the plant install project to capture an energy cost saving of $341,000 annually.

And Now, the Engineering Method Approach

As a result of the plant visit, the following 3 energy projects are proposed to capture a total saving of $358,000 annually. Coupled with the financial benefit is the environmental enhancement, through greenhouse gas emission reduction, of 5000 tons of CO_2, 78 tons of SO_x and 15 tons of NO_x.

Proposal No. 1

Modify the operation of the centra-vac system using both the primary motor (75 hp) and the standby unit (40 hp—it's interesting that the standby unit is much smaller!)

1. *Current Situation*
   The centra-vac system with its primary 75-hp motor was observed to be running constantly round the clock regardless of the need for it. Inspection during off hours and weekends confirmed this observation.

2. *The Required Operating Condition or Constraints and Criteria*
   Vacuum must be available at the moment's notice. People are in the plant sporadically and unpredictably off shift although the main traffic is from 6 AM to 6 PM.

3. *Solutions*
   - Alternative No. 1: leave it the way it is
   - Alternative No. 2: install a time clock for automatic switching to the standby motor

*Recommended solution: administratively enforce the action by writing it in the standard operating procedure (SOP) to require the operator to manually switch to the smaller standby motor at 6 P.M during his or her tour of the plant.

4. *Quantified Analyses*
   Please refer to Attachment A (spreadsheet) for detailed engineering calculations of the solutions (alternative and recommended). The recommended solution yields the following summary:
   - Current cost = $34,635/yr
   - Proposed cost = $23,546/yr
   - Resultant cost saving = $11,089/yr
   - Required investment = 0
   - Simple payback period = Immediately

5. *Conceptual Design*

- Construction—none is required.
- Testing—it is recommended that the plant implement the proposal and pay attention to any complaints with regard to the serviceability of the vacuum system in the plant. The test shall last for one

month to allow for fluctuation of off-hour plant activities. Record the following data during this one-month test (1) kW of the 75-hp motor, (2) kW of the 40-hp motor.

6. *Final Evaluation of the Solution*

The solution satisfies the initially identified constraints and criteria with regard to the serviceability and operability of the centra-vac system. It also yields excellent annual saving at no investment cost.

7. *Action Item*

This energy opportunity has excellent rate of return, immediate payback period, and simple constructability. We recommend it for a high priority energy action item.

Proposal No. 2

Repair a stuck-open air-operated condensate pump, which continuously vents compressed air.

1. *Current situation*

   The air supply valve under consideration is to open upon the increasing level of the condensate in the system to allow compressed air to flow to pump the condensate down to a low level at which point the valve will return to a close position stopping compressed air flow. This air supply valve has been stuck in the open position, allowing highly compressed air to flow continuously regardless of the condensate level in the condensate collection tank
2. *The Required Operating Condition or Constraints and Criteria*

   Condensate must be pumped, as required, to ensure proper operation of the steam system round the clock.
3. *The Solutions*
   - Alternative No. 1: Free up the valve and install a detection system to set off an alarm if compressed air flows continuously for a preset duration (thus prevents this from happening again).

*Recommended solution: Repair the valve to return it to the designed condition.

4. *Quantified Analyses*

   Please refer to Attachment A (spreadsheet) for detailed engineering calculations of the solutions. The recommended solution yields the following summary:

- Current cost = $6,527
- Proposed cost = $272
- Resultant cost saving = $6,255
- Required investment = $400
- Simple payback period = 0.06 year (less than a month)

5. *Conceptual Design*
   - Construction—none.
   - Testing—free up the valve and verify that the valve opens and closes as condensate level changes with normal operating condition.

6. *Final Evaluation of the Solution*
   The solution as recommended meets the criteria as initially identified and eliminates waste of steam and compressed air resources at the same time.

7. *Action Item*
   This energy opportunity has excellent rate of return, immediate payback period, and simple constructability. We recommend it for a high priority energy action item.

Proposal No. 3

Capture vented live steam from the thermal oxidizer operation.

1. *Current Situation*
   The audit revealed a plume of high quality steam being vented continuously to the atmosphere as a result of the operation of the thermal oxidizer operation. Depending on the weather, the steam can supply the thermal load of the plant in the winter. During the 5 non-winter months, however, the excess steam of 36,000 pounds per hour (pph) is wasted. The vented steam is of high quality at 125 psi.

2. *The Required Operating Condition*
   The thermal oxidizer has to be in operation around the clock to render thermal destruction of the VOC loading of the plant. Steam production is a product and cannot be curtailed.

3. *The Solutions*
   - Alternative No. 1: Leave it the way it is. This option ignores the great potential savings financially and environmentally.
   - Alternative No. 2: Sell the excess steam. This option involves contractual obligation to guarantee someone else's production, which may not be the core interest of the plant.

*Recommended solution: Install a 2000-kW turbine driven generator utilizing high pressure steam that is being otherwise wasted. 36,000 pph of steam will be utilized. The cost saving comes from not having to buy electricity and 2000-kW demand in the summer months.

4. *Quantified Analyses*
   Please refer to Attachment A (spreadsheet) for detailed engineering calculations of the solution. The recommended solution yields the following summary:
   - Current cost = $360,765
   - Proposed cost = $20,000
   - Resultant cost saving = $340,765
   - Required investment = $650,000
   - Simple payback period = 2 years
   - Internal Rate of Return = 55 percent

5. *Conceptual Design*
   - Construction—Hire a design/build engineering firm to do engineering, design, and construction. Purchase a turbine-generator condensing unit.
   - Testing—Ask for a simulation of the design prior to full-scale purchasing and construction.

6. *Final Evaluation of the Solution*
   Wasted steam is fully utilized while thermal load and operation of the thermal oxidizing unit are maintained.

7. *Action Item*
   This energy opportunity has excellent rate of return, immediate payback period, and simple constructability. We recommend it for the highest priority energy action item.

DISCUSSION

It was clear that, when presented side by side with a report using the engineering method, the qualitative approach of writing and presenting the energy proposal would not sell. It was also clear that the application of the engineering method took a much longer time for the obvious reason: quality, credibility, and convince-ability.

Use of a spreadsheet attachment to display the quantification of the savings proved to be a wise tactic because it allowed the plant manager the opportunity to (1) check the calculations himself; (2) validate the proposal by changing certain parameters to conduct a sensitivity analysis; and (3) show that the engineer-auditor has done his homework and carefully considered alternatives. This is made possible if the spreadsheet contains live formula and highlighted cells indicating variables or assumptions.

CONCLUSION

An energy project is an engineering project and because of that, should be subject to engineering method. It has been shown in this article that the application of this method can do more toward obtaining approval for energy ideas and projects. It projects a favorable image of professionalism and thoroughness on the part of the auditor. The engineering method, when applied to the writing of an energy audit report, or to any engineering report for that matter, provides a framework for structured thinking, discussing, concluding, and communicating. In the author's experience with his numerous energy audits around the world, no plant customers ever rejected any energy cost saving proposal and all "can't wait until our next profitable, no-cost-low-cost audit."

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ABOUT THE AUTHOR

Dr. Van currently is chair of the Engineering Department at Union University, where he teaches mechanical and environmental engineering and also manages the department through its start up phase to ABET's Engineering 2000 criteria. In his 20 years in the industries, he had extensive worldwide experience in the engineering, management, and assessment of energy, utility, and wastewater systems in corporate facilities, manufacturing plants of pharmaceutical, confectionery and consumer health products. He initiated, implemented, and managed numerous projects that resulted in excess of 45 million dollars in corporate energy savings. He had worked with the US EPA in its many innovative energy and environmental initiatives. Dr. Van is both a mechanical and environmental engineer with advanced academic training in each discipline. His primary research interests are energy conversion and conservation and the treatment of drinking water and wastewater.

Appendix A

Analyses of Energy Options

Proposal No. 1 Make Use of the Standby Unit During After-hours

(hp) (0.746 kw/hp) (loading factor of 85%) (24 h/d) (7d/wk) (52wks/yr) ($0.085/kwh)
Note: each cell is live and contains computational formula such as this one to facilitate understanding and allow for sensitivity analysis (if desired).

Alternative 1: Leave it the way it is

* Current operating cost =	$34,635	
* Proposed operating cost =	$34,635	(unchanged from current cost)
* Resultant Savings =	0	(current cost - proposed cost)
* Required Investment =	0	(none from doing nothing)
* Payback period =	na	(investment/annual savings)
* Internal rate of return =	extremely low	

Alternative 2: Install a time clock for automatic switching to the standby motor of 40 hp during off-hours and weekends or from 6 pm to 6 am during the week and for the entire weekend.

* Current operating cost =	$34,635	
* Proposed operating cost =	$23,546	
* Resultant Savings =	$11,089 per year	
* Required Investment =	$1,300	(2 man-day at $50/hr and $500 for materials)
* Payback period =	0.12 year or over one month long	
* Internal rate of return =	33 %	

(corporate hurdle rate of 14% and a tax bracket of 38%)

(Continued)

Alternative 3: Write a standard operating procedure (SOP) to administratively require the operator to manually switch to the standby motor at 6 PM.

* Current operating cost = $34,635
* Proposed operating cost = $23,546
* Resultant Savings = $11,089 per year
* Required Investment = $0
* Payback period = Immediately
* Internal rate of return = extremely high

Excellent financial benefit coupled with the following environmental protection:

71 tons CO_2 reduction
1 tons SOx reduction
0 tons NOx reduction

<u>**Proposal No. 2**</u> Repair the Air-operated Condensate Return Pump

Alternative 1: Free up the valve and install a detection system to alarm if compressed air flows continuously for a preset duration.

* Current operating cost = $6,527 (as a result of compressed air flows at 90 psi through 1/4" pipe)
* Proposed operating cost = $272
* Resultant Savings = $6,255
* Required Investment = 1250 (allow for 5 man-day and a sensor, a solenoid valve and wiring)
* Payback period = 0.20 year or about 2.5 months
* Internal rate of return = 487%

(corporate hurdle rate of 14% and a tax bracket of 38%)

Note: Other factor than investment cost needs to be considered. In pharmaceutical plant such as this one, consider impact on validation program.

(Continued)

Alternative 2: Free up the valve

* Current operating cost =	$6,527	(as a result of compressed air flows at 90 psi through 1/4" pipe)
* Proposed operating cost =	$272	
* Resultant Savings =	$6,255	
* Required Investment =	$400	
* Payback period =	0.06 year of less than a month	
* Internal rate of return =	Extremely high	

Excellent financial benefit coupled with the following environmental protection:

40 tons CO_2 reduction
0 tons SOx reduction
0 tons NOx reduction

<u>**Proposal No. 3**</u> Harness the High Quality Vented Steam

Alternative 1: Leave it the way it is

(plant load) (5 months of a full year) (transformer efficiency)
(cost of electricity) + (plant load) (monthly demand charge

* Current operating cost:

1. Electrical: (partial plant load)	2000 kw * 3650 hrs/yr * 0.97 * $0.033/kwh + 2000 kw * $(8.35 - 0.45)/ kw-mo * 5 mos/yr =	$312,673
2. Water: (required to make wasted steam of 36000 #/hr)	4320 gal/hr * 3650 hrs/yr * $0.0017/gal =	$26,806
3. Chemical treatment: (for feedwater)	4320 gal/hr * 3650 hrs/yr * $0.00135/gal =	$21,287
	Grand Total ===>>>	$360,765

* Proposed operating cost:	0 (from doing nothing)
* Resultant Savings =	0 (from doing nothing)
* Required Investment =	0 (from doing nothing)
* Payback period =	na (from doing nothing)
* IRR =	na (from doing nothing)

(Continued)

Alternative 2: Sell excess steam

General consensus is the plant is not interested in getting into this business. People rather focus in their core business.

Alternative 3: Install a 2000-kw turbine driven generator utilizing 125 psi steam at 36,000 pounds per hour that is currently wasted

* Current operating cost = (as calculated previously)			$360,765
1. Electrical:	2000 kw * 3650 hrs/yr * 0.97 * $0.033/kwh		
	+		
	2000 kw * $(8.35 - 0.45)/ kw-mo * 5 mos/yr =	$312,673	
2. Water:	4320 gal/hr * 3650 hrs/yr * $0.0017/gal =	$26,806	
3. Chemical treatment:	4320 gal/hr * 3650 hrs/yr * $0.00135/gal =	$21,287	
* Proposed operating cost =			$20,000
1. Electrical:		$0 (from the generator)	
2. Water:	negligible makeup and blowdown	$0 (reuse from steam condensate)	
3. Chemical treatment:	"	$0 (reuse from steam condensate)	
4. Maintenance:		$20,000 (as suggested by the vendor)	
* Resultant savings =			$340,765
* Required Investment =			$650,000
Package Turbine-Generator Condensing Unit		$400,000	
Engineering, Design, Construction & Materials		$250,000	
* Payback period			2 years
* Internal Rate of Return =			55 %
(corporate hurdle rate of 14% and a tax bracket of 38%)			

Excellent financial benefit coupled with the following environmental protection:

3,986 tons CO_2 reduction
37 tons SOx reduction
15 tons NOx reduction