Why is this Facility Different? Measuring Energy Culture to Achieve Continual Improvement in Energy Efficiency

Ulrika Wising, Ph.D., DNV GL
Jingjing Liu, P.E., DNV GL (presenter)
Julia Vetromile, DNV GL

ABSTRACT

Improving industrial energy efficiency faces many barriers, most of them neither technical nor financial. Organizations with better energy management have a strong energy culture. Energy culture is the shared mindset that creates and sustains an environment that supports continual improvement of an organization's energy performance. It comprises people, systems, structure, skills, and strategy, and often involves behavioral change. The strength of an energy culture can be measured for improvement. Establishing a vibrant energy culture addresses the non-technical and non-financial barriers to achieving potentially available savings. Determining an existing energy culture can be achieved with diagnostic approaches including:

- Data analysis to understand current energy consumption
- On-site surveys designed for a particular facility for large data collection
- Interviews with management to complement and confirm the survey, followed by identification of non-technical barriers and issues faced in daily work
- Evaluation of diagnostic results showing maturity level in key aspects of energy culture such as visibility, accountability, collaboration, commitment, progress, and targeting

After assessing the current energy culture, a culture baseline can be determined and behavioral changes instilled. For example, an organization may have strong commitment, but minimal sub-metering, resulting in limited awareness of its energy consumption. The baseline can help an organization develop and implement plans to move toward the culture it seeks. This paper provides a case study of how DNV GL evaluated energy culture for a chemical processing facility.

Introduction

Industry Needs Dramatic Energy Efficiency Gains

Industry has made significant progress in adopting energy efficiency practices and reducing CO_2 emissions in the last 20 years. US Energy Information Administration (EIA) data in a recent report show that energy-related CO_2 emissions in the industrial sector have decreased since 1990 (Sustainable Development Solutions Network [SDSN] and Institute for Sustainable Development and International Relations [IDDRI] 2014). Utility incentive programs across the nation and federal and local government initiatives have played an important role in this progress. However, there is much room for improvement, and even more dramatic energy efficiency gains are critical for US industry to stay competitive while minimizing climate change.

The report also stated that, by 2050, global industrial emissions will account for 51% of total emissions, up from 31% in 2010. This means that it is imperative for industry to use energy more efficiently, which is also stated as part of a principal strategy for the US in this report. The report further noted that industry sector CO_2 emissions have to decrease 83% from 820 metric tons in 2010 to 140 metric tons in 2050. It will take major steps to get there.

Behavior Change is the Key

Industry recognizes that "widgets and gadgets" measures alone are far from sufficient to achieve far-reaching energy efficiency improvements, and that behavioral change is a key enabling strategy to achieve continuous and deep energy savings. This is because human behavior ultimately decides whether/how energy efficiency is taken into account in the policy and procedures for procurement, production, operations and maintenance which affect the energy efficiency of the business. As a result, mechanisms for continual energy improvement (CEI) have become one of the most important themes for industrial energy efficiency programs in the US during the last 10 years. CEI typically has a behavioral component, and is often used interchangeably with the term strategic energy management (SEM), which is a combination of training, technical support, and peer networks that encourages owners and operators of industrial facilities to adopt continuous improvement techniques in energy management. As opposed to traditional measure-by-measure programs, CEI and SEM programs promote taking a holistic approach to energy management and following a Plan→Do→Check→Act framework to sustain the energy performance improvement cycle. Additionally, the involvement of senior management drives successful behavioral change.

DNV GL has piloted a CEI program with a Midwest utility since 2012. By May 2015, the program had successfully engaged 28 customers and identified more than 17,300,000 kWh of electricity and 160,000 MMBtu of natural gas energy savings. 29% of the identified measures through energy assessments are operations, behavior or maintenance measures representing 40% of the customers' annual energy costs. The utility rebate program has attained energy savings of more than 5,500,000 kWh of electricity and 12,000 MMBtu of natural gas from customers since beginning participation with the CEI program. DNV GL is also working with the program evaluation team to develop an approach to capture energy savings from implementing operations, behavior and maintenance measures under utilities incentive programs.

As is evident in this example, the potential for energy improvement due to behavior change is large. For example, Superior Energy Performance® (SEP) program[1] participants were found to generate the majority (74%) of their energy and cost savings from operational energy performance improvements, which have no or low costs (Therkeleson, et al. 2013).

Yet many energy efficiency initiatives fail to capture these types of savings. There are several possible reasons for this phenomenon. First, the action plan is developed following an energy assessment, which is usually conducted by a professional with industrial energy audit experience. Typically, an audit focuses on technical rather than behavioral solutions. Second, most audits lack a systematic approach to behavior change opportunities. During an assessment, obvious behavior-related opportunities, such as avoiding using compressed air to blow chips and turning off the lights after employees leave, are likely to be captured. However, there are many

[1] Superior Energy Performance is a U.S. Department of Energy certification program requiring third party verified ISO 50001 compliant energy management systems and energy performance improvement.

other behavior-related opportunities that are much less obvious to identify without a more comprehensive and quantitative approach.

Behavior change is critical to energy management. It is essential for maintaining and continually improving practices, and has a low implementation cost compared with many technology solutions. The challenge is engaging industry in behavior-based energy efficiency. Literature suggests that contextual factors, such as corporate culture and investment strategies, may present strong inertial forces within organizations that inhibit implementation of actions that appear technically rational (Shaha 2003). Next, we present a methodology to develop and enhance energy culture in industrial organizations.

Develop a Strong Energy Culture to Drive Further Improvement

The energy culture concept draws inspiration from behavioral models and theories of change. It is a comprehensive approach to assess and improve an organization's energy culture and, thereby, reduce its energy costs.

The Four-Stage Energy Culture Approach

The approach of energy culture contains four stages, as illustrated in Figure 1 below. The first stage is the diagnosis. To identify potential savings and understand how to capture the gains, the maturity of an organization's energy culture is assessed. This stage typically includes surveys, interviews, workshops, observations, and an energy variability analysis. The variability analysis is the main focus of this report and will be discussed in more detail later. During the information gathering process, questions are raised covering the following eight themes:

- Visibility of energy consumption in the organization: if people performing tasks do not have the necessary information available, they cannot include that information into their decisions and consequent actions,
- Accountability of energy, e.g., presence of an on-site energy manager,
- Collaboration and communication about energy: sharing ideas increases an individual's knowledge and information, thereby triggering the correct action,
- Targeting, measuring, and reporting of energy performance and recommendations for corrective actions,
- Commitment to energy: if the company has an energy policy,
- Motivation to increase energy efficiency,
- Learning about energy and energy consumption: a way to gain confidence in an individual's ability to perform a certain action or task, and
- Progress and continuous improvement assessment.

These eight themes are evaluated not only to get a better understanding of an organization's behavioral model and ability to change, but also to understand what tools have already been implemented and what are available. They are also used to identify barriers to energy efficiency and ways to overcome them.

The second stage focuses on solution development by creating an action plan that reflects the organization's maturity level, ambition, commitment, and available budget for creating an energy culture. This plan encompasses awareness, metering, effective planning, standard operating procedures, and continuous improvements. It includes activities related to the change

process such as setting up a task force, developing a communication plan, removing barriers, and creating quick wins to motivate people.

In the third stage of implementation, the immediate savings identified during the diagnosis phase are implemented first. These quick wins are necessary to create momentum to help drive the process. Tools used include training, developing energy dashboards, improving reporting, designing a KPI (key performance indicator) structure, creating a communication plan, and establishing an energy consumption baseline to track progress.

To reach the final stage of sustaining the achieved savings, it is very important to measure progress compared to the baseline. This process is done while identifying and implementing new saving opportunities, thereby closing the cycle of continuous improvement.

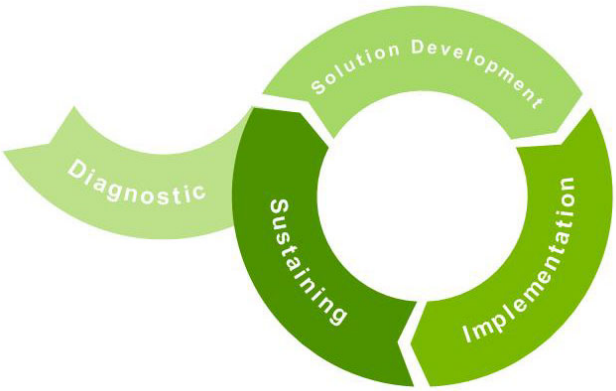

Figure 1. Energy culture four-stage approach

Measuring Energy Culture with Eight Themes

Visibility of energy consumption can be a cue to action by providing information that might trigger individuals to make decisions. If a person performing a task does not have the necessary information available, they will not include that information into their decision and consequent action. It is important to note that the use of information provided heavily depends on how an individual perceives it. **Accountability** is a response to the perception of what is expected and the consequences for not meeting expectations.

Collaboration is also a cue to action. Collaboration is the sharing of ideas that would increase an individual's knowledge and information that would then trigger the correct action. It could also generate self-efficacy if it increases an individual's sense of competency. **Targeting** is part of response efficacy, but only in combination with a recommendation for corrective action. Providing evidence that recommended responses will avert negative consequences is an integral part of effective targeting.

Commitment is an individual's intent to perform a specified behavior. It is also a form of consistency of behavior defined in cognitive dissonance theory, which suggests that individuals have a need to keep attitudes and beliefs in harmony. Conflicting thoughts often create internal discomfort, which motivates behavior that will restore balance. The theory also suggests that commitment sets the stage for subsequent consistent behavior.

Motivation is the reason and enthusiasm for action, and is very closely linked to perceived benefits. The benefits can be of different form such as recognition, achieving goals, and monetary rewards. Motivation is also linked to subjective norms and attitudes. **Learning**, like collaboration, can generate self-efficacy by providing confidence in an ability to perform a certain action or task. **Progress** is linked to response efficacy where there is a perception that a certain response will prevent negative results. Group efficacy is positively related to effectiveness when uncertainty is low, so progress is also a measure of uncertainty.

Maturity Levels of Energy Culture

In each of the eight categories, an organization's performance can be expressed as a maturity level. Table 1 contains some examples of the typical conditions to which the different levels correspond. As can be seen, both systems and behavioral aspects interrelate in many instances and most improvement actions will have an impact on multiple aspects.

Table 1. Maturity levels

	Maturity Level	Examples
1	Inert	No or limited information on energy performance is available. There is no energy-related training provided.
2	Reactive	Energy is measured via on-site utility meters only, which are recorded manually at irregular/long intervals. Poster campaigns are organized to generate awareness.
3	Involved	Part of management bonuses are based on energy performance. Plant-wide energy performance is illustrated on screens and/or boards throughout the facility.
4	Proactive	Energy use of main energy users is measured in real-time and is automatically analyzed and stored. A regular self-assessment process is carried out by Energy Champions.
5	Continually improving	A comprehensive and real-time metering structure is in place, covering both main energy users and main energy drivers. Energy performance is discussed on a daily basis at all level of the organization.

The result of an evaluation can be presented as a spider web with interrelated factors. A disturbance on one strand in the web can be felt in another part. This is illustrated in the case study presented later in this paper.

Improving Energy Culture with an Action Plan

After the behavioral assessment, a 12–24 month action plan can be developed to improve the energy culture. This action plan also depends on the organization's maturity level, ambition, commitment, and budget. Based on the different themes, different systems and actions can be recommended. Examples of this can be seen in Table 2.

Table 2. Recommended actions

Themes	Examples
Visibility	Cues to action Make energy reports available to all employees Incorporate energy KPIs in management/governance system
Accountability	Subjective norms and fear Give each energy KPI an owner Assign actions to people and follow-up
Collaboration	Cues to action and self-efficacy Create cross-functional team that works on energy-performance issues Have energy manager from different departments meet on a regular basis
Targeting	Response efficacy Implement dynamic targets on all energy drivers and KPIs Put systems in place to identify reasons for drift from normal operation
Commitment	Intentions Make sure that management leads by example Collect and implement energy improvement ideas
Motivation	Benefits Implement incentive programs for all employees linked to energy Link bonuses to energy efficiency performance
Learning	Self-efficacy Create a know-how retention program Highlight and communicate all energy initiatives
Progress	Response efficacy and uncertainty Implement a comprehensive energy metering system Create a continuous improvement group focused on energy

Case Study

This methodology was implemented at a chemical plant mainly producing silicones and their derivatives. The site employs around 700 people working in administrative, research, and operational roles. The site had already realized many energy efficiency projects, as well as fuel switching to achieve greenhouse gas reductions. It had identified behavioral change as an opportunity to achieve even more energy savings and greenhouse gas reductions. As a first step, the site began implementing energy metering to track its energy performance in real time.

The first step of the project was to assess the energy culture. We sent two different surveys, one customized for personnel in the manufacturing process and one customized for administrative, research and development, and laboratory staff. The members of the management committee were interviewed and workshops were held with both engineers and operators.

Tools for Measuring Energy Culture

Variability Study

An important step in improving the energy efficiency of an industrial, energy-intensive site is the calculation of the savings potential. This calculation is carried out through a variability analysis of the energy-consumption pattern of the site. By reducing the variability of this pattern, significant energy savings can be realized without capital investments. We conducted a variability analysis by analyzing production data in combination with related energy-consumption data to identify factors influencing the energy consumption that can be controlled by operational activities or automation. Once we identified these factors, an action plan was developed to solve problems related to suboptimal operational activities or automation.

Surveys

The two surveys we administered each had several questions related to each one of the dimensions. Examples of questions can be seen in Table 3.The response rate for the survey was 40% and served as the main input to the spider web diagram.

Table 3. Example questions

Theme	Example Question
Visibility	Do you have real-time information regarding your equipment's energy use?
Accountability	Is there an energy manager on-site?
Collaboration	Is there a forum to discuss energy?
Targeting	Is energy performance measured and reported in the same way as production/quality?
Commitment	Do you know if there is a company energy policy?
Motivation	Is there an improvement box where you can put your ideas for energy efficiency improvement?
Learning	Have you received any energy training?
Progress	Is there a continuous improvement group within the company?

Interviews

The 11 members of the management committee were interviewed. The interviews were used to corroborate and complement the results of the surveys. In particular, non-technical barriers, such as communication challenges between engineers and operators, were identified during the interviews that would have been difficult to identify through the surveys. The interview template followed the same type of format as the survey, with questions for each one of the dimensions. Mostly open-ended questions were used, as quantitative data already was available through the two surveys. The results of the interviews validated the spider web diagrams from the surveys and served as the main input parameter to the recommendation in the action plan.

Workshops and Observations

Five different workshops were held, two with personnel from the engineering department and three with operators from production. The main purpose of the workshop was to observe a

group discussion on the variability of energy use on a specific installation. Results from the surveys were further corroborated and both technical and non-technical barriers to the change process were identified. In addition, a list of quick wins was established. Workshops were conducted and observations made in different control rooms in the production facilities. These workshops helped corroborate survey results and provide insight on how personnel perform their duties and how energy could be incorporated in those duties. The observations also helped gain a better understanding of existing tools that could be used to facilitate the implementation phase.

Measured Results of the Energy Culture

Figure 2 presents the measured results of our evaluation of the energy culture in the form of a spider web diagram. Visibility was a particularly weak dimension. The organization had already identified this observation and began actions to improve visibility. Commitment was the strongest dimension as was evident throughout the study. Results from surveys, interviews, workshops, and observations corroborated the high score for commitment. This is an important factor for the change process as well, as change takes time and endurance.

Figure 2. Results spider diagram

An action plan was developed as well, and examples from that action plan can be seen in Table 4.

Table 4. Examples from action plan

Scenario	0-6 months	6-12 months	12-18 months	18-24 months
Ambitious	Create a vision to change energy culture. Identify quick wins. Identify Energy Champions in main areas.	Develop an optimal KPI structure from the bottom-up with roles and responsibilities. Create quick wins. Develop baselines for main energy users.	Set targets for KPI structure. Re-launch a poster campaign with figures related to energy savings. Develop or update standard operating procedures.	Develop an incentive program including ideas collection, analysis, selection, and implementation. Identify best practices in targeted department.
Challenging	Develop an action plan to achieve the targets of the energy policy.	Develop a continuous improvement group focused on energy.	Develop dynamic targets for KPI structure.	Develop a bonus program that considers energy use.

This action plan is also laid out in a spider web diagram in Figure 3, where the projected levels for each dimension are shown for the two scenarios: ambitious and challenging. The ambitious scenario aims at increasing the dimensions' scores approximately half a point and the challenging scenario one point.

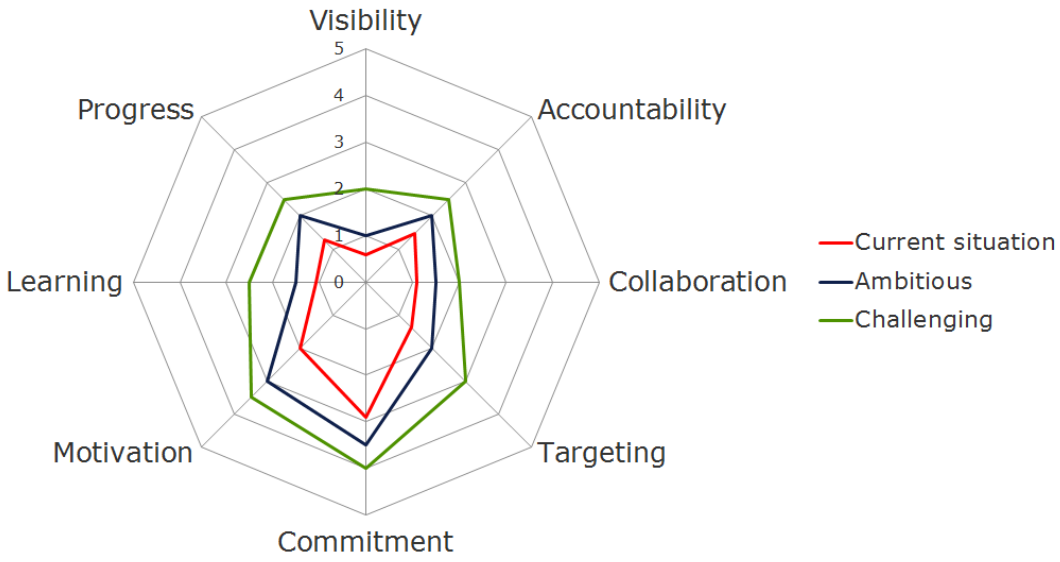

Figure 3. Targeted levels with the action plan

The organization is beginning to implement the action plan and metering. The project has created momentum in the organization and the action plan aims to support the momentum for sustainable long-term gains. Once these steps are completed, the quantitative results from implementing the action plan can be measured.

When is Energy Culture Appropriate?

Whether an organization considers itself advanced in managing energy or it is just starting to take charge of its energy usage, implementing energy culture can add significant value because it is different from any of the energy management systems and approaches we discussed earlier. Energy culture implementation takes an operational excellence approach to manage energy through driving desirable human behavior changes and, hence, achieving continual improvement of an organization's energy performance. There is still significant opportunity for improving energy efficiency in industry, and human behavior change is one of the most important opportunities.

Why is Having an Energy Management System and Energy Improvement Goal not Enough?

One important advantage of government-sponsored continuous improvement programs is that they provide participating organizations with a higher level of visibility and a way of enhancing their public image by pledging to an advanced energy improvement goal. DOE's Better Buildings, Better Plants program, SEP™, and EPA's ENERGY STAR Challenge for Industry are good examples. These programs play a very important role in driving the industry to achieve aggressive energy-performance improvement and identifying the industry leaders in this regard. They tackle the energy problem by elevating its importance to the partners' senior management through a public commitment strategy, addressing an extremely important aspect of energy management.

In addition, all these programs follow the Plan→Do→Check→Act approach to energy management, although not all prescribe a rigorous energy management system. However, there is much more to effectively managing energy, even if an organization is SEP certified, for example.

The essence of successful continuous energy management is making it an established culture and expectation, ensuring that no steps will be skipped regardless of who manages the process. However, discovering improvement opportunities still relies on people rather than the system. Although implementing an energy management system promotes taking a more holistic approach, a project and technology focus will still dominate without a systematic method to address behavior impact on energy performance. Ultimately, it is the people who operate energy-consuming equipment that are making decisions on how the equipment will work. The equipment may be labeled with high-efficiency ratings and attached to sophisticated energy management software, but if the operators have undesirable energy behaviors, the benefits of hardware and software technologies cannot be fully harvested.

Many organizations with advanced energy status believe they have already implemented most of the common "low-hanging" energy efficiency measures. Energy culture provides the methods to go deeper and achieve more savings. Opportunities in human behavior change are significant and usually affordable. We only need a systematic approach to identify them. Fortunately, the energy culture approach is extremely adaptable to any existing energy

management system structure. It contains a handful of tools for identifying and realizing behavior change-based energy improvement opportunities, and it is viable and flexible to incorporate these tools in existing energy management systems. The energy culture approach also works effectively for organizations without energy management systems, delivering continuous results with a structure.

Energy Culture as a Program Offering

Behavior programs have gained wider recognition and adoption in the US recently, proliferating across the residential sector (York 2013). More behavior-based campaigns and pilots are emerging in the commercial and industrial sectors, although many implementation and regulation challenges still exist (Mazur-Stommen 2013).

According to Mazur-Stommen (2013), one of the key challenges is the lack of cost-effectiveness data. The industry needs successful examples of behavior change implementation as well as clearly demonstrated energy savings and program costs. We believe that the energy culture approach will work well as a technical assistance program offered by utilities, governments, and non-profit organizations to the industry. The program sets the framework for assessing current energy culture, identifying focus areas and goals, developing action plans, implementing changes, measuring progress, and continuing the cycle. As a core value offering, it could provide an implementation consultant to assist partner organizations to bring necessary expertise on behavior science, assessment tools, solutions, and measurements. Given the low-cost nature of behavior measures, we are confident that the energy culture approach will prove itself both cost-effective for the industry partners to implement and cost-effective as a resource program for utilities to harvest energy savings.

As suggested earlier, the energy culture approach is extremely adaptable to any energy management structure an organization may have. Similarly, as a program offering, it is also possible to be included as a component in existing industrial energy management programs. Either as a stand-alone program or as a program component, it may also benefit from some level of financial incentive on energy savings achieved. However, this should not change technical assistance from being the core value of the program offering.

Conclusion

This paper presents the foundation, specification, and validated application of a generalized methodology to assess and improve an organization's energy culture. It is a novel approach that draws inspiration from both behavioral models and theory of change. It covers many of the key elements of behavioral models and is thus a comprehensive approach to behavioral change in industry. The case study demonstrated how a chemical plant applied the methodology to further implement change.

CEI/SEM both target continuous and deep energy savings, follow the Plan→Do→Check→Act framework, require senior management commitment, and leverage assessment leading to action plans. However, energy culture brings a systematic approach to assess and change human behavior as it relates to energy. It provides a set of tools to measure the intangible culture and targets operational excellence by driving behavior changes. Utility and government programs can leverage the approach as a resource for energy efficiency, while any organization interested in improving its energy performance can benefit from implementing the methodology even if an energy saving goal and energy management system are already in place.

It is flexible enough to be implemented as a stand-alone technical assistance program or designed as a component to existing CEI/SEM programs.

References

Church, G., K. Widdison, and J. Reese. July 2013. "Evaluating a Three Year Continuous Energy Improvement Program." In *Proceedings of the ACEEE 2013 Summer Study on Energy Efficiency in Industry*, Niagara Falls, NY.

Jones, T., et al. July 2011. "The Evolution of Continuous Energy Improvement Programs in the Northwest: An Example of Regional Collaboration." In *Proceedings of the ACEEE 2011 Summer Study on Energy Efficiency in Industry*, Niagara Falls, NY.

Mazur-Stommen, S. and K. Farley. 2013. *ACEEE Field Guide to Utility-Run Behavior Programs. December 2013*. Washington, DC: ACEEE.

Therkelsen, P., R. Sabouni, A. McKane, and P. Scheihing. July 2013. **"**Assessing the Costs and Benefits of the Superior Energy Performance Program." In *Proceedings of ACEEE Summer Study on Energy Efficiency in Industry*, Niagara Falls, NY.

SDSN (Sustainable Development Solutions Network) and (ISDIR) Institute for Sustainable Development and International Relations. 2014. *Pathways to Deep Decarbonization – Interim Report.* http://www.iddri.org/Publications/Pathways-to-deep-decarbonization-Interim-2014-Report

Shaha, R. and P. Ward. 2003. "Lean Manufacturing: Context, Practice Bundles, and Performance," *Journal of Operations Management*, 21 (2), 129–149.

York, D., et al. January 2013. *Frontiers of Energy Efficiency: Next Generation Programs Reach for High Energy Savings*. Washington, DC: ACEEE.