Compressed Air Efficiency – Moving Beyond Custom Programs

Nikhil Gandhi, Strategic Energy Technologies
Michael DiGiacomo, Wisconsin Electric Power Company

Compressed air is a vital utility for an industrial plant. Besides maintenance applications, compressed air is heavily used in many industrial processes, accounting for 10-13 percent of electrical energy consumption. The technical potential estimated at 25-30 percent of the compressed air end-use consumption ranks next only to that of high efficiency electric motors systems in the industrial sector.

With few exceptions, utilities have included air compressor efficiency improvements as part of custom rebate programs, which may not always take a comprehensive view of all opportunities available to reduce compressed air energy consumption. To ensure that the new generation of DSM programs move the market to high-efficiency designs while at the same time maintain persistent savings in a profitable manner, Wisconsin Electric Power Company (WEPCO) has been piloting a value-based End-Use Pricing Service for the HVAC and refrigeration end uses (the theme originally presented by Thomas Edison—sell lighting not electricity).

Encouraged by the results of the pilot program, WEPCO decided to investigate if this concept can be extended to industrial air compressors. This paper describes the planning activities that have preceded the design of a compressed air End-Use Pricing pilot program. The planning process included analyzing and evaluating compressed air efficiency improvement techniques from an end-use pricing perspective; examining issues such as measure persistence, reliability, liability, installation risk, customer acceptance and maintenance; and identifying attractive markets from the technical potential estimate. This paper also discusses advantages of a Compressed Air End-Use Pricing program over conventional DSM programs and describes program initiatives being considered by WEPCO.

Introduction

For most industrial plants, compressed air is an important utility that typically accounts for 10-13 percent of electric bills. Some industries such as pulp and paper, beverages, food and metal production use more compressed air than others. Whereas applications of compressed air are diverse and industry-specific, its primary uses are for process, plant maintenance and instrument control purposes. For most industrial customers, a reliable supply of compressed air is more important than efficiency in its production and use, which is one of the reasons for lower penetration of energy-efficient compressed air systems.

Many techniques are available that could save 40 to 50 percent of a plant's compressed air usage. Some of this huge potential has already been tapped through the custom industrial program offered by WEPCO under the umbrella of the Smart Money program. However, custom air compressor projects chosen by customers did not include a broad set of possible efficiency measures. Achieving additional savings would require addressing barriers such as high capital investments, long payback periods and perceived risks associated with more efficient technologies. WEPCO felt that approaches such as End-Use Pricing (EUP) may be needed to capture the remaining efficiency improvement potential of industrial air compressors.

EUP is a totally new concept in electric service for Wisconsin Electric commercial and industrial customers. Under an EUP agreement, WEPCO, working through its trade allies, owns, designs, installs, operates and maintains new refrigeration, HVAC or lighting systems on the customer's premises, in return for a flat fee that appears as part of the customer's regular electric bill. In essence, instead of buying electricity to operate end-use equipment, the customer is buying performance-a service contract for a specified amount of lighting, cooling or refrigeration.

The flat fee is guaranteed for the first five years of a 10 or 15-year contract. The fee is negotiated at the end of five years or the customers has an option to buy the equipment at a pre-determined price. At the end of the contract duration, the equipment may be purchased by the customer for a dollar.

EUP offers significant advantages to the customer, including:

- elimination of up-front capital investment
- predictable, level costs that can be expensed over the contract duration
- elimination of performance risks
- elimination of responsibility for on-going equipment maintenance, which can be costly
- in the case of some technologies, relief from the burden of compliance with a multitude of environmental regulations.

Through this pilot program, WEPCO installs more efficient systems by overcoming many barriers that now prevent customers from installing innovative energy-conscious design. It also serves to showcase proven but under-utilized technologies. The most appropriate EUP applications are situations where a significant amount of energy can be saved in a cost-effective manner that would not normally be pursued by the customer.

The utility can play an important role in moving the market to higher levels of energy-efficiency by leveraging its DSM experience. This market-based approach ensures that energy efficiency persists because degradation of efficiency over time will reduce the profitability of End-Use Pricing. The EUP Customers are unaffected by retail rates and the utility must ensure that the least amount of electricity is used for specified performance.

Research Issues for End-Use Pricing

Encouraged by the success of the EUP pilot program for HVAC and refrigeration end uses, WEPCO decided to investigate the feasibility of applying the EUP concept to industrial air compressors. A number of questions, including some listed below, needed to be answered to assess the feasibility of supplying compressed air to industrial customers, in return for a fee.

1. Is the energy saving potential large enough to offer an EUP program for compressed air? If so, what are the target markets?
2. Can the efficiency of air compressors be sustained?
3. Are there any liability issues in controlling compressed air?
4. How intensive are maintenance requirements?
5. What are the customer acceptance issues?
6. Is there a measurable basis to determine the fee?
7. Will this service be profitable?

The Research Approach

WEPCO developed a comprehensive plan to research program design issues and understand ways in which the energy efficiency of compressed air systems can be improved. The objectives of the initial phase were to:

- characterize the market of industrial air compressors;
- identify and evaluate more efficient air compressor technologies from the end-use pricing perspective;
- understand the perceptions of plant managers regarding compressed air efficiency and implementation issues; and
- review the collected information to assess if the end-use pricing service for compressed air was feasible.

The market characterization and analysis of end-use pricing issues were conducted using secondary sources and interviewing manufacturers. The data sources included the EPRI technical brief, published articles and papers, manufacturers' catalogues, and data from previous research conducted by WEPCO. Major air compressor manufacturers, pneumatic control equipment manufacturers, and a distributor were interviewed.

Customer acceptance issues were identified through focus groups of customers from four industry segments. The focus group research investigated the use of compressed air, maintenance practices, the efficiency of compressed air systems; and barriers to acceptance of compressed air efficiency improvement programs.

Important Findings

The key findings of the initial research are described in this section. These include target markets, measure analysis and liability, savings persistence, the fee basis, and maintenance and customer acceptance considerations.

Target Markets

WEPCO had collected statistically representative data on the installed air compressor HP in all industrial subsectors and estimated compressed air end-use consumption for some of these subsectors. From this data, equivalent full load operating hours for a subsector were calculated by dividing the end-use estimate with the installed air compressor HP. These were then applied to the installed HP of industrial subsector for which the air compressor end-use estimate was not available. The resulting end-use estimates for the five capacity ranges are shown in Table 1.

Table 1. Air Compressor End-Use Estimates

Capacity Range (HP)	Installed HP	Air Compressor End-Use in MWH
25-75	53,037	43,067
75-150	43,964	96,563
150-200	19,324	42,534
250-500	23,262	48,435
Over 500	17,855	32,553
Total	157,443	263,152

Based on the experience of HVAC and refrigeration pilot programs, WEPCO felt that high transaction costs will make it difficult to cost-effectively service small customers in a compressed air EUP program. Large customers with installed air compressor capacity in excess of 200 HP would have significant usage of compressed air that may result in sizable projects. With this initial assumption made, the data on installed air compressor HP in smaller facilities were excluded from the analysis shown in Table 1.

The air compressor end-use consumption of large customers was estimated at 263,152 MWH which is about 4 percent of WEPCO's industrial sales[1]. Based on the technology analysis and the knowledge of experts, the technical potential from improving the efficiency of air compressors was estimated to range from 25 to 40 percent of the end-use consumption. Figure 1 shows the relative importance of the sixteen industrial segments analyzed. Since the technical potential is proportional to the end-use consumption of a subsector, the data represents the share of industrial segments as a percentage of the total compressed air usage or technical potential.

Besides the miscellaneous durable and non-durable goods sectors, relatively high compressed air usage was found in the metal cans, metal forging, engine and turbine manufacturing, construction and mining equipment manufacturing, iron and steel foundries, and paper mills subsectors. As the initial screening criterion, facilities with on-peak demand exceeding 1.5 MW could be targeted as they are more likely to have installed air compressor capacity in excess of 200 HP. Further market segmentation based on the installed HP, compressor types, processes, importance of compressed air, maintenance practice, etc., will identify potential participants for an EUP program, but this was deferred for subsequent research.

Measure Analysis and Liability

The compressed air end-use pricing concept is analogous to generation, distribution and use of electricity by customers. To better understand the interactive impact of measure savings, measure persistence and potential liability issues arising from installing and maintaining equipment on customers' premises, efficiency improvement opportunities were studied using a similar framework. Table 2 shows compressed air efficiency measures grouped into three categories, i.e., production, distribution and the use of compressed air.

The measure analysis showed that while most savings potential could be captured by installing measures related to compressed air production, the full DSM potential cannot be tapped unless WEPCO maintained and controlled the compressed air distribution lines in a customer's plant. For example, air distribution lines will require periodic inspection and maintenance to ensure that air leaks are fixed. The cost of supplying compressed air at specified air pressure increases because air leaks increase the demand for compressed air. Similarly, point-of-use controls save energy by reducing the demand for compressed air, but controls may be bypassed or adjusted by plant personnel, losing their effectiveness.

The higher full load efficiency (higher cfm per kW) of an air compressor while being important, may not have much impact in a partially loaded system that has poor part load efficiency. In such cases, the benefits of better full load performance of more efficient air compressors may not be fully realized. The performance of a partially loaded

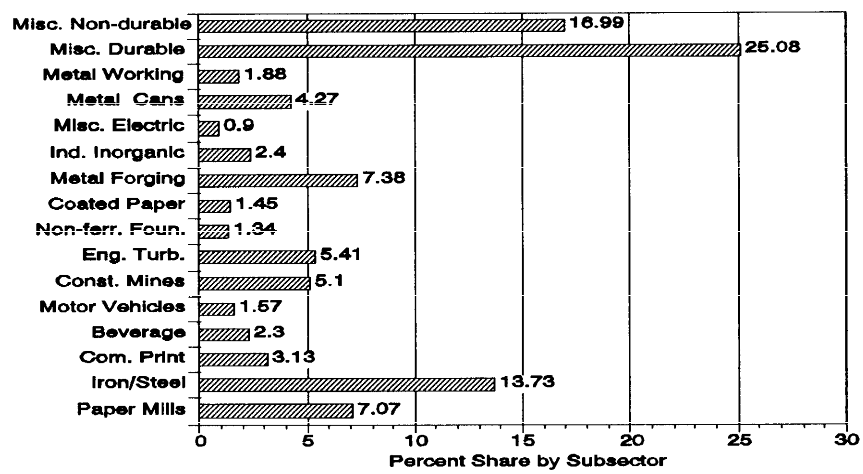

Figure 1. Relative Importance of Industrial Subsectors

Table 2. Air Compressor Measures

Production of Compressed Air
Replace inefficient air compressors with more efficient machines
Install multiple air compressors with staging controls
Install aftercoolers/intercoolers/efficient dryers/heat recovery equipment
Variable speed drives
High efficiency motors
Replace inefficient belts and drive systems with cogged belts or helical gears
Install more efficient compressor controls
Use synthetic lubricant
Distribution of Compressed Air
Redesign piping layout and pipe sizing
Reduce compressed air pressure
Use pulsating jets instead of continuous jets for cleaning
Install intermediate storage with controls
Eliminate air leaks
Point-of-Use Improvements
Install and automate point-of-use controls
Replace pneumatic tools and controls with electric equivalents

system can be improved in a many ways by using control methods such as load/no load controls, intermediate storage, staging air compressors, etc. The highest level of efficiency is possible to achieve in a system that is free of air leaks, operates in a manner to match the air supply and demand, and uses the most efficient equipment; thus, a package of measures, not component improvements, will achieve the highest savings.

Installing more efficient equipment is fairly straightforward but this approach does not necessarily achieve the highest system efficiency. The two other strategies mentioned above, i.e., efficient operating practice and proper maintenance, are essential to achieving the highest installation efficiency. Implementing these strategies requires a thorough understanding of the air demand profile and access to air distribution system which raises potential liability issues for an EUP program.

Additional liabilities could arise from the failure to supply compressed air when needed. The latter can be addressed by renting air compressors while repairs are in progress or by installing reserve capacity. On the other hand, supplying compressed air at specified pressure at the header (the header is the main distribution line for compressed air from which air is piped to sub-headers and branch lines within the plant), and leaving maintenance and control of distribution lines to customers, liability issues can be minimized. However, in this case, it is possible to attain the highest efficiency only for the equipment used in production of compressed air. The level of efficiency that can be attained, the degree of control over equipment and liability are the trade-offs to consider in developing a compressed air EUP program.

Maintenance Requirements

Because WEPCO operates and maintains equipment over the EUP contract duration, maintenance costs affect the contract profitability. Therefore, more efficient technologies were studied to evaluate the associated maintenance requirements and the impact of maintenance on system efficiency.

Maintenance cost is an important component in the life-cycle costing of a measure or a package of measures. Because the initial cost, efficiency, equipment life, maintenance requirements and performance degradation over time vary for different technologies, care must be exercised in selecting technologies. For example, rotary screw compressors offer the advantages of lower initial cost and lower maintenance requirements but they are less efficient and have lower life expectancy compared to reciprocating compressors. On the other hand, the higher initial efficiency of reciprocating compressors will deteriorate over time, if they are inadequately maintained.

A good maintenance program provides for daily recording of critical performance parameters such as air temperature and pressure, monitoring oil levels, and checking the condition of air filters. Periodic draining of water from the distribution system, air receiver, aftercoolers and intercoolers must be done. Monthly checks are needed to identify and fix air leaks. Similarly, semi-annual and annual inspections are required for all mechanical components including the drive, bearings, lubricating pumps, etc.

Technology advancements have automated and simplified some of these maintenance tasks. For example, microprocessors can monitor the air temperature and pressure and transmit the data over a phone line. Microprocessors can even monitor the condition of air filters and signal when replacement is needed. Automatic solenoid controls are available to drain the water from air receivers and other components.

The manufacturers and distributors interviewed indicated that maintenance contracts are now becoming the norm. Major distributors have the expertise required to provide basic maintenance services. In addition, more complex and innovative maintenance programs are being offered by major manufacturers. By selecting technologies that require less maintenance and then taking advantage of state-of-the-art maintenance contracts, the maintenance cost of an EUP contract can be minimized.

Savings Persistence

As mentioned above, a well-designed but improperly maintained installation may lose its efficiency over time, eventually costing more to supply air than originally anticipated. By selecting appropriate technologies, automating maintenance checks and performing required maintenance, the efficiency of equipment used in the production of compressed air can be sustained. The savings persistence in the distribution and use of compressed air depends on the level of equipment control allowed in the contract.

The reduced profitability resulting from the loss of savings persistence can be minimized by ensuring that risks and rewards (for WEPCO and customers) are consistent with performance responsibilities. Two end-use pricing options emerged for consideration, i.e., supplying compressed air at the header or at the point-of-use. Table 3 compares these options on four important dimensions—equipment control, measure persistence, liability and maintenance requirements.

Table 3. Comparison of End-Use Pricing Options

	Air Supply at Header	Air Supply at Point-of-Use
Equipment Control	Production System	Production and Plant Air Distribution System
Savings Persistence	High	Moderate
Maintenance Requirement	Moderate	High
Liability	Moderate	High

The Basis for End-Use Pricing

In the EUP pilot program for the refrigeration and HVAC end uses, WEPCO charges a fixed monthly fee on electric bills. This concept can be extended to supplying compressed air only in cases where the air demand is predictable. Large variations in end-use requirements and air leaks can quickly wipe out profits built into the fixed monthly fee. The consumption of compressed air, however, can be metered in cubic feet per minute (cfm) with a flow meter and customers can be billed accordingly. A customer may then use as much compressed air as needed and pay for the actual consumption. In this case, the customer bears the risk of degradation in the efficiency of air distribution system. While it is important to determine the basis for pricing compressed air, it is equally important to ensure that sufficient capacity is installed to meet the peak demand. This can be done after monitoring a plant's air demand over a month or two, and then negotiating the maximum capacity with the customer.

Customer Acceptance Considerations

The focus group research mentioned earlier found that all industrial customers were fairly similar in operational experience and expressed similar concerns and needs regarding the use of compressed air. In general, large customers were more aware of energy efficiency issues and they were more involved in operating and buying equipment. Large customers knew more about efficiency improvement opportunities. However, all respondents considered the reliable supply of compressed air more important than energy efficiency. The need to keep air compressors running was extremely important which would make the EUP program more marketable because it takes the burden of maintenance away from the customer.

Overall, respondents were aware of what was happening to their compressed air systems. The problems such as air pressure drops or fluctuations, air quality and system leaks were very well known. But, respondents were not fully aware of possible solutions. Not surprisingly, the respondents were not aware of the cost of compressed air in relation to the operating cost. The three important barriers to improving the efficiency of compressed air systems were identified as the lack of: time, financial resources, and knowledge of the trade-off between cost-benefits and reliability of more efficient options. The research revealed positive response to the concept of an Air Compressor Service Program.

Conclusions

The pre-feasibility study showed that the concept of end-use pricing can be extended to compressed air. Many elements of the current EUP pilot program will apply to a compressed air EUP program. Reliable and proven technologies are available to improve the efficiency of compressed air systems and infrastructure exists to support such program. The fee charged by WEPCO will have to be structured on the basis of cfm of compressed air supplied instead of a flat monthly fee.

The study also showed that by installing, owning, operating and maintaining equipment used in production of compressed air, WEPCO can achieve higher end-use efficiency compared with that achieved by current programs, As a supplier of compressed air, WEPCO will have more incentive to produce and supply compressed air at the lowest cost by leveraging cost-effective technologies. With an EUP program, customers will be relieved of pressures to ensure that reliable supply of compressed air is available.

In order to better assess it the highest system efficiency can be achieved or not, further research is required to investigate issues related to realizing and maintaining savings by improving the performance of compressed air distribution system and point-of-use controls. WEPCO is currently studying these aspects, evaluating the profitability of supplying compressed air, and assessing the possibility of implementing an EUP pilot program for compressed air. Simultaneously, a program to assist customers in maintaining air compressor systems is being considered for implementation.

Endnote

1. This estimate excludes industrial customers with installed air compressor capacity less than 200 HP and a few very large customers who could have skewed the results at the SIC level.

References

"End-Use Pricing and Thermal Storage put Kenosha School District's Energy Program in a Class by Itself." *Energy Management Trends,* Volume 1, No, 3, Third Quarter 1993.

"DSM That Pays and Stays: Wisconsin Electric Moves into the Grocery Business." *The DSM Letter*, Volume 21, No. 18, August 30, 1993.

Internal Unpublished Reports of Wisconsin Electric Power Company, 1991-1993.