Final Report

# Compressed Air Systems Market Assessment In the Public Service Electric and Gas Service Territory

**May 2001**

**Presented to:**
**Public Service Electric and Gas**
**Pacific Energy Associates**

**AMSG 7537-001**

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## Compressed Air Systems Market Assessment
## In the Public Service Electric and Gas Service Territory

**May 2001**

**Presented to:**
**Public Service Electric and Gas Company**
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**AMSG 7537-001**

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# Executive Summary

Public Service Electric and Gas (PSE&G) industrial customers spend about $35 million a year on compressed air. Experts in New Jersey and elsewhere estimate that 30 percent of that expenditure, $11 million, is unnecessary and can be cost-effectively eliminated. Even with a savings potential of $23,000 per year per customer, facility managers with at least 100 horsepower (hp) of air compressors rank compressed air management only 13th on their list of priorities. They have taken little action in the last two years to eliminate waste.

This market assessment lays a foundation for Public Service Electric and Gas (PSE&G) to develop strategies to improve the efficiency of industrial compressed air systems in the region by:

(1) Characterizing the industrial end-user market regarding compressed air equipment, usage, and management capability;
(2) Describing the market structure and delivery system, including market barriers;
(3) Establishing metrics and a baseline that describe typical current market and end-user practices related to compressed air system efficiency; and
(4) Suggesting possible strategies for overcoming barriers, achieving energy savings, and market transformation.

**Characterization of the compressed air system end-user market.** PSE&G has 1,508 industrial customers, of which 326 are estimated to have at least 100 horsepower (hp) of non-back-up air compressors. These larger customers operate 68 percent of the total compressor load in PSE&G's territory. The average customer spends nine percent of their electric bill on compressed air. Table 1 summarizes typical industrial customer compressed air characteristics.

### Table 1: PSE&G Industrial Compressed Air Population Statistics by Estimated Non-Backup Compressor Plant Size

| Parameter | Size | | | Total |
|---|---|---|---|---|
| | Sub-small Under 100 hp | Small 100 to 500 hp | Large Over 500 hp | |
| Number of industrial customers | 1,182 | 275 | 51 | 1,508 |
| Total compressor hp | 50,000 | 53,000 | 54,000 | 157,000 |
| Average compressor hp | 67 | 200 | 1,100 | 100 |
| Average annual compressed air energy bill | $9,500 | $43,000 | $249,000 | $23,000 |

As would be expected, PSE&G's largest customers spend the most money on compressed air and are likely to be the most interested in utility assistance in reducing such costs. They also have been more active in managing their systems in the past. Forty-four percent of large end-users either installed engineered nozzles or eliminated air-using equipment in the last two years, compared with 23 percent of small end-users. Large end-users were three times as likely to use a multi-compressor control system. Small customers were almost twice as likely to use the less efficient and less expensive but more convenient modulation-only form of part-load control. Furthermore, large customers were almost four times more likely to have conducted an optimization study. Although the last three statistics indicate far more activity by large end-users, neither group has been aggressive. Neither group of customers is sufficiently active in compressed air efficiency to support a self-sustaining market for such services.

The chemical industry, which includes pharmaceuticals and cosmetics, requires about 20 percent of all compressor horsepower in the PSE&G service territory and is more than 50 percent larger than the next largest industry as measured by both numbers of businesses and total estimated compressed air horsepower. More generally, process industries (food, textiles, paper, chemicals, and petroleum) make up 41 percent of all compressor loads. PSE&G may want to target process industries because of the amount of compressed air they use, but suppliers offered few technical reasons to target them or other particular industries.

When suppliers were asked where the biggest sources of waste in their customers' compressed air systems could be found, they consistently cited sources outside of the compressor room. Table 2 lists their responses.

### Table 2: Biggest Sources of Waste in Compressed Air Systems

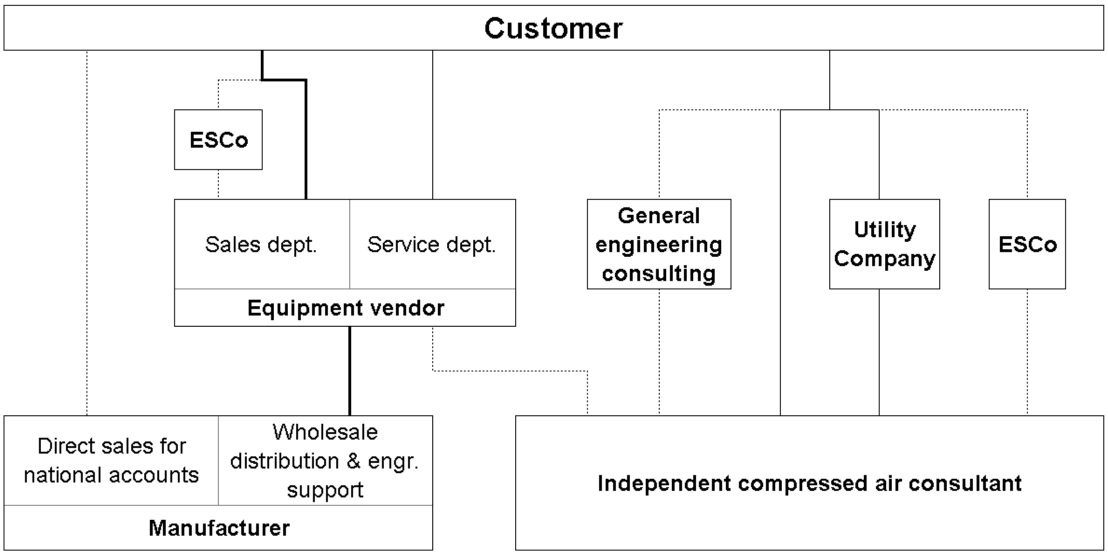
| *Source of Waste* | *Number of Times Selected by Suppliers (n=11)* |
|---|---|
| Leaks | 8 |
| Excessive pressure in system | 6 |
| Oversizing plus poor part load control | 5 |
| Inappropriate use of compressed air | 5 |

Other answers, none chosen more than twice, included poor compressor sequencing, poor maintenance, poor distribution system design, poor central plant design, inefficient compressors, and inefficient auxiliary equipment.

End-users have a reasonably good general sense of where in their compressed air systems they waste the most energy if not the cost of that waste. They estimate that 69 percent of the waste is outside the compressor room, which correlates well with the above table, but they have not been responsive to unsolicited proposals from suppliers to reduce their compressed air costs. This lack of response may be in part because they prefer to use to their incumbent contractor. Customers perform a moderate level of operations and maintenance activity on their own to reduce their compressed air costs, but their efforts are not systematic.

**Compressed Air System Market Structure and Delivery Systems.** Figure 1 illustrates the flow of services between customers and suppliers and among suppliers. By far the strongest relationship is between the customer and the traditional vendor.

### Figure 1: Compressed Air Service and Equipment Supply Channels




All interviewed suppliers provide some type of compressed air equipment to their clients. Only one of the companies does not provide any additional compressed air-related services, although several suppliers' services are quite limited. Half of the suppliers provide additional products other than compressed air equipment and services.

Suppliers can be distinctly split into two groups: suppliers that understand the importance of system-wide compressed air system management, and suppliers that believe that compressed air service means solely keeping the compressed air plant running without placing a burden on the plant engineer. The progressive suppliers often must operate like their more traditional counterparts in order to be responsive to customer requests. Three of the eight interviewed vendors are judged to be willing and capable of providing system-wide optimization services either by themselves or with subcontractors. The three progressive firms share three common traits:

1. They are larger than their competitors,
2. They conduct business both in New Jersey and outside the state, and
3. They have been or are currently affiliated with nationally known compressed air experts.

During early market transformation efforts, these firms are likely to be far more receptive to outreach than traditional compressor-only-oriented firms. Whereas systems-oriented firms would welcome individualized utility support, other companies are likely to be non-responsive to even enthusiastic systems-oriented outreach at this time.

End-users' biggest barriers to increasing the priority given to compressed air systems efficiency and suppliers' perceptions of their customers' barriers are shown in Table 3.

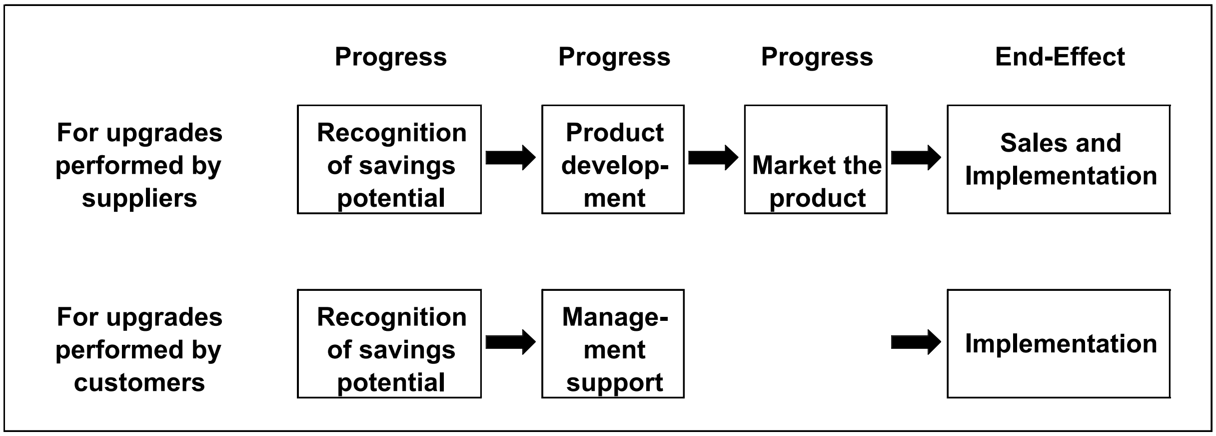
## Table 3: Barriers to Compressed Air System Upgrades

| End-User Barriers To Implementing Compressor Efficiency Upgrades | Number of Citations (First Choice) |
|---|---|
| ACCORDING TO END-USERS (n=25) | |
| Floor users don't realize how expensive compressed air is | 19 |
| Payback times are too long | 18 |
| Can't interrupt 24/7 operation | 10 |
| Inertia/"If it ain't broke don't fix it" | 9 |
| Not a big cost for my operation | 8 |
| Lack of time for engineer (downsizing) | 6 |
| Lack of upper management support for cost-cutting investments compared to Expanding production or R&D (no capital available) | 5 |
| Lack of training to identify problems or estimate savings | 5 |
| ACCORDING TO SUPPLIERS (n=11) | |
| Don't have available capital | 6 |
| Unaware of magnitude of savings | 5 |
| Payback times are too long | 3 |
| Don't care/stubborn/fear of unknown | 3 |
| Unaware of opportunities | 2 |
| Don't trust supplier savings claims | 2 |
| Need executive involvement | 2 |

Both customers and suppliers believe that payback times are too long. Based on the opinions of compressed air system experts around the country, this is a misguided concern, at least in part. Much of the savings available from compressed air upgrades can be achieved without capital investment, or with investments that pay for themselves in less than two years. Presuming this is true, the real barrier is not actually long payback times but a lack of education about opportunities, their low cost, and their fast payback times. This barrier is prominent explicitly elsewhere on the list, and is an excellent target for utility market transformation activities. Compounding all of the barriers is the fact that staff responsible for compressed air plant operation typically are not accountable for utility bills. Therefore they are not inclined to initiate time-consuming energy-saving projects until they are faced with a major project funded from their own budget or staffed from their own labor pool, such as buying an additional compressor.

**Metrics describing current market and end-user practices related to compressed air system efficiency.** There is no single factor that defines current energy efficiency practice. The study uses a combination of indicators to measure "end effects." End effects are direct indicators of efficiency-related sales and system improvements. In an immature efficiency market, measuring intermediate progress towards the desired end effects is advantageous. For example, before a supplier sells a service or product, they must understand the issues technologically, develop the product to sell, and market it. Before a customer implements a project either internally or by purchasing it from a supplier, the customer needs to learn why the project is worth doing, and the facilities engineer must acquire management support to fund the project. These intermediate steps that mark progress are illustrated in Figure 2.

### Figure 2: Stages of Progress Leading to Implementation




Overall, the compressed air equipment and services market in New Jersey falls far short of capturing available savings through sales and implementation. Without intervention by interested parties or gross changes in market factors (such as major electricity price increases), the market will not change its pattern of behavior. The market has only progressed 20 to 30 percent of the way from one that ignores energy waste beyond the compressor to one that aggressively eliminates it throughout the compressed air plant, air distribution system, and end-uses.

*Supplier Sales and Implementation.* The market is not active when compared to the number of financially viable opportunities. Customers do not seek out system-wide efficiency studies. Twelve percent of the end-users interviewed had studies performed on their compressed air systems in the past two years. On average only one compressed air optimization project was implemented last year for every two suppliers.

*End-User Implementation.* Implementation of recommendations from a compressed air system-wide study may optimize performance for a brief time but will only have a lasting effect if plant staff, including floor employees, follow preventive maintenance procedures and measure system performance regularly. This is lacking in New Jersey. Only seven percent of end-users routinely walk their compressed air distribution lines checking for leaks, for example. Twenty-three percent of them have installed engineered nozzles or eliminated compressed air-using equipment in the last two years, a relatively high number.

*Progress Indicators.* End-users demonstrate good basic understanding of their compressed air costs, although larger customers tended to underestimate the percentage of their electricity use for compressed air. They also demonstrate good general understanding of waste sources. They still do not put a high priority on eliminating waste. They certainly are not demanding associated products and services from the market at large. Basic understanding of costs and waste has not inspired action. Suppliers are confident in their ability to find waste and, by their high proportion of savings estimated in the distribution system, demonstrate at least a general understanding that maximum savings will come from a system-wide approach. They promise they can save their customers 24 to 27 percent on average.

Training opportunities have been limited. Only half of the suppliers had heard of the Department of Energy (DOE) Compressed Air Challenge and attended training. None of the customers had attended any compressed air training in the last two years, but all of them are interested in doing so.

The majority of suppliers do not promote system-wide efficiency services proactively. Instead, they concentrate on traditional needs such as replacing compressors. Those that do promote such services have limited success within the service territory. If dedicated to such business they must operate out-of-state as well to keep business levels high. While thirty percent of the customers acknowledged being approached by suppliers unsolicited, only two percent of them have bought the promoted service so far.

**Recommendations.** Because the compressed air efficiency market is not mature, many different program activities can positively influence market behavior. Due to the lack of basic understanding of compressed air efficiency, Aspen recommends two primary points of emphasis for early program development:

- Customer training, and
- Individual support of the vendors that promote system-wide optimization.

More than anything else, customer training is needed to foster demand for system-wide compressed air efficiency services. Since the majority of customers already can estimate their compressed air costs and the larger customers (and more desirable ones to influence) already perform routine and often intermediate-level maintenance on their systems, trainees will not be compressed air novices. Training content needs to quickly advance beyond compressed air basics and emphasize savings opportunities.

Group seminars are the most common training medium and likely would be cost-effective given that the target audience is only about 300 customers and that DOE might offer funding, marketing, or staff support, but customers would welcome other alternative approaches. End-users often prefer training formats that require less time than do workshops. Consider technical topic videos. Videos are also more likely to attract smaller manufacturers who cannot take the time to attend off-site seminars. The four most desired training topics cited by customers are (1) optimizing compressed air system operation; (2) air compressor controls; (3) Finding and eliminating leaks; and (4) basic operations and maintenance.

In concert with training Aspen recommends individual support for suppliers that demonstrate commitment to system-wide efficiency upgrades. Specific support that would be beneficial includes case studies with demonstration before-after power metering, training for customers led by these suppliers, and training of these suppliers by experts from other parts of the country. If possible to do without compromising utility objectivity, suppliers would appreciate PSE&G directing customers interested in system-wide upgrades to them.

The above two recommendations are believed to be most important at this stage because they address the first two progress stages. Additional intervention can help as well. Possible actions follow, by progress and end-effect stages.

- Funding compressed air system optimization services;
- Developing a screening worksheet to help engineers identify customers that are candidates for optimization services;
- Aggressively promoting load reduction at the time of prospective compressor replacement, when customers appreciate the value of potential capital expenditure avoidance;
- Buying and then offering free use of ultrasonic leak detector for customers to use to detect leaks;
- Funding auxiliary equipment purchases such as receiver, demand expanders, and variable speed drives to improve compressor part load efficiency; and
- Supporting standardization and widespread use of compressor efficiency ratings.

# 1.0 Introduction

Pneumatic drills cost up to 20 times as much to operate with compressed air compared to electricity. Why is it so expensive? Air compression is an inefficient energy conversion process compared to other transformation processes (especially at part load), cooling and drying compressed air requires energy, air distribution systems have substantial losses, and the turbines that convert energy in the compressed air into rotating power have efficiency losses. Each loss compounds with the other to make a system that uses substantial amounts of energy. For every prudent use of a cubic foot of air, there is likely to be an equal amount of waste due to leaks or misapplication. Research of Department of Energy (DOE)-sponsored Industrial Assessment Center data shows that over 80 percent of compressed air upgrade recommendations do not require capital investments such as purchasing new compressors and motors. Instead, auditors more often recommend low-cost systemic upgrades and operations and maintenance (O&M) measures. Compressed air experts often project payback periods of less than two years for such improvements.

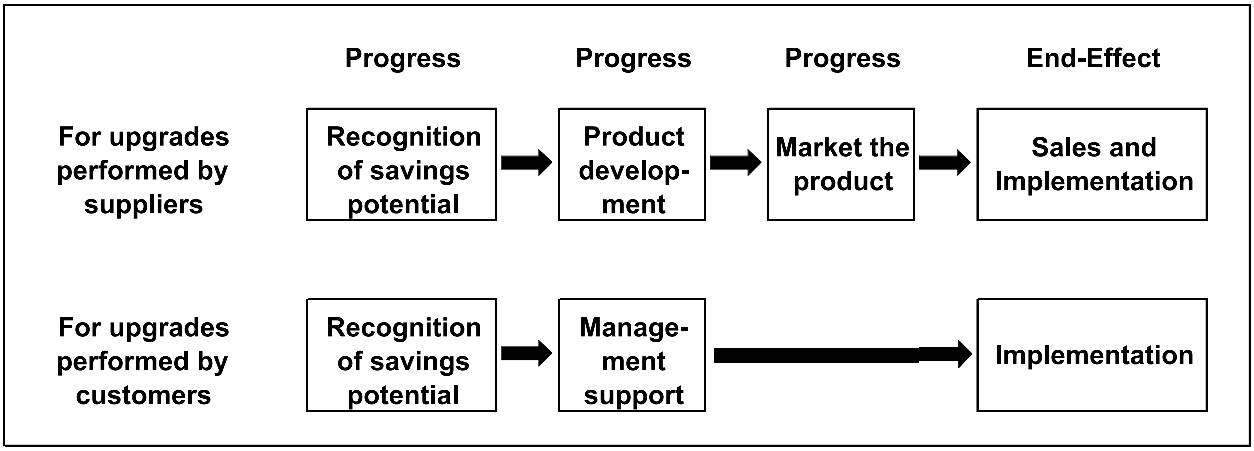
This market assessment lays a foundation for Public Service Electric and Gas (PSE&G) to develop strategies to improve the efficiency of industrial compressed air systems in the region. This market assessment:

- Characterizes the industrial end-user market regarding compressed air equipment, usage, and management capability;
- Describes the market structure and delivery system, including market barriers;
- Establishes a baseline and metrics that describe current market and end-user practices related to compressed air system efficiency; and
- Suggests possible strategies for overcoming barriers, achieving energy savings, and market transformation.

This research started shortly after a similar study was completed in New England. A generally parallel structure has been retained to facilitate regional comparative analysis.

An important goal of the project was to determine how well the market supports PSE&G customers with system-wide compressed air efficiency services. Excellent support is the desired end effect. Measuring intermediate progress towards the desired end effect helps gauge the state of the market. Figure 3 illustrates the stages of market progress that must be accomplished before the desired end-effect of implementation occurs. The structure provides a frame upon which subsequent analysis is built. Before a customer implements an upgrade project, either with internal staff or with the assistance of a supplier, the customer needs to learn why the project is worthwhile, and the facilities engineer must obtain management support to fund the project. Of course the supplier must have the product to offer. The market barriers, metrics, baseline, and recommendations sections of this report are all organized around these five stages of progress and the two desired end-effects.

## Figure 3: Stages of Progress Leading to Implementation




Following this introduction, Section 2, Findings, is divided into three subsections. In the first subsection, the current compressed air market structure in Public Service Electric and Gas' (PSE&G) territory is characterized, including customer compressed air loads, savings potential, population, and plant management. Second, the greater market is examined with a focus on supplier delivery channels and barriers to system-wide efficiency sales. Third, indicators of current supplier and customer behavior are reviewed for baseline scoring and for comparison and reevaluation with the same questions in later years.

Section 3, Conclusions, summarizes Aspen's interpretation of the findings.

Section 4, Recommendations, presents policies and programs for PSE&G to consider in creating a self-sustaining market that helps industrial customers increase their compressed air system efficiency.

The Appendixes include a section on the research methodology and discussion of the sampling procedure and results. The Appendixes also include copies of the two final survey instruments and tabulated data.

# 2.0 Findings

The compressed air market in Public Service Electric and Gas' (PSE&G) service territory falls far short of capturing available savings from system-wide compressed air waste elimination. Even with an estimated total savings potential of $11 million dollars per year and $23,000 per year per customer, end-users rank compressed air management 13th on their list of priorities. Most of them do not hear compelling stories from their suppliers to persuade them to do otherwise. Only 12 percent of the end-users interviewed had any studies performed on their compressed air systems in the past two years.

This survey revealed two distinct types of suppliers. The more progressive suppliers are committed to assembling resources necessary to offer their customers system-wide optimization services. Such suppliers tend to be consultants or larger vendors, and they tend to have business associations both inside and outside of New Jersey. Progressive suppliers have nationally renowned in-house staff or strong affiliations with equally renowned consultants. In contrast, traditional suppliers tend to be smaller, locally-oriented vendors who work hard to meet their customers' explicitly stated compressor sales and repair needs without garnishment. There is a striking gulf between the two types of suppliers; few firms fall in between the distinct categories.

## 2.1. Characterization of End-User Market

The market characterization starts with a review of typical compressed air loads, based primarily on the responses of end-users. Loads are defined as both the compressed air plants and the equipment that requires compressed air. Next, the general market profile includes an estimate of savings potential, a closer look at the compressor population, and finally, a qualitative review of end-user management capability and executive-level support.

**2.1.1. Compressed Air Loads.** This research project focuses specifically on industrial customers who have over 100 horsepower (hp) total non-backup compressors for 90-120 pounds per square inch gage (psig) plant air.[1] To design effective programs, it is necessary to understand characteristics of the prospective market. Table 4 shows the industries in the PSE&G service territory that require the most significant compressed air resources.[2]

[1] The customer survey excluded those under 100 hp to maximize the value of each of those 25 interviews. However, the study analysis includes all industrial customers when estimating the number of businesses in PSE&Gs territory by size and type (Tables 4 and 5) and when estimating savings potential (Tables 8 and 9).
[2] Table data is based on PSE&G industrial population data, assumed percent energy to compressed air, motor efficiency, and load factors. Percent energy values are 6.77 percent (SIC 20, 21, 22, 26, 28, 29), 15.1 percent (32, 33), 17.77 percent (34, 37, 38, 39), 5.17 percent (23, 24, 25, 27, 30, 31), and 7.91 percent (35, 36), from *The NEES Companies C&I Data Development Project—Market Profiles Report, Regional Economic Research, March 1995, p. 7-3.* Assumed motor efficiency and load factors are 93 percent and 102 percent respectively.

**Table 4: Number of Businesses by Standard Industrial Classification (SIC) and Total Compressed Air Horsepower by SIC and Size**

| SIC | Description | Number of Businesses | Total Compressor Horsepower by Size Class <50 hp | 50-100 hp | 100-500 hp | >500 hp | Total |
|---|---|---|---|---|---|---|---|
| 20 | Food and Kindred Products | 128 | 2,296 | 2,233 | 5,219 | 1,445 | 11,193 |
| 21 | Tobacco Products | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | Textile Mill Products | 64 | 1,482 | 753 | 273 | 1,449 | 3,957 |
| 23 | Apparel, Textile Products | 36 | 799 | 138 | 158 | 0 | 1,095 |
| 24 | Lumber and Wood Products | 6 | 92 | 58 | 0 | 0 | 151 |
| 25 | Furniture and Fixtures | 13 | 292 | 0 | 0 | 0 | 292 |
| 26 | Paper and Allied Products | 113 | 2,037 | 2,073 | 4,003 | 1,561 | 9,674 |
| 27 | Printing and Publishing | 137 | 2,627 | 989 | 1,123 | 556 | 5,294 |
| 28 | Chemicals and Allied Products | 292 | 5,156 | 4,608 | 8,566 | 12,851 | 31,181 |
| 29 | Petroleum and Coal Products | 28 | 580 | 352 | 741 | 545 | 2,218 |
| 30 | Rubber and Plastics | 174 | 3,121 | 2,500 | 3,583 | 0 | 9,204 |
| 31 | Leather and Leather Products | 8 | 117 | 118 | 0 | 0 | 235 |
| 32 | Stone, Clay, and Glass Products | 43 | 359 | 787 | 3,336 | 5,464 | 9,946 |
| 33 | Primary Metals Products | 94 | 842 | 1,913 | 8,150 | 9,604 | 20,509 |
| 34 | Fabricated Metal Products | 108 | 775 | 3,322 | 6,237 | 5,553 | 15,887 |
| 35 | Industrial Machinery | 74 | 1,450 | 1,057 | 958 | 564 | 4,030 |
| 36 | Electronic Equipment | 83 | 1,499 | 1,434 | 1,949 | 623 | 5,505 |
| 37 | Transportation Equipment | 13 | 45 | 238 | 1,289 | 6,974 | 8,546 |
| 38 | Instruments, Related Products | 55 | 49 | 1,503 | 5,864 | 6,670 | 14,085 |
| 39 | Miscellaneous Mfg. Industries | 39 | 144 | 1,864 | 1,483 | 0 | 3,491 |
| **Total** | | **1,508** | **23,763** | **25,940** | **52,932** | **53,860** | **156,494** |

The chemical industry, which includes pharmaceuticals and cosmetics, is more than 50 percent larger than the next largest industry as measured by both numbers of businesses and total estimated compressed air horsepower. The chemical industry requires about 20 percent of all compressor horsepower in the PSE&G service territory.

Customers with over 100 hp of compressor motors represent about two-thirds of the total horsepower in PSE&G's service territory. Customers with over 500 hp are about one-third of the total. This concentration of use makes larger customers attractive targets for early intervention efforts. They have more money at stake per customer and a high proportion of the total expense as well.

Tables 5 and 6 illustrate this data categorized by major industry group, and expressed as percentage of population installed non-backup horsepower. Figure 4 shows the number of businesses by SIC groups.

**Table 5: Number and Percentage of Businesses by SIC Group and Total Compressed Air Horsepower**

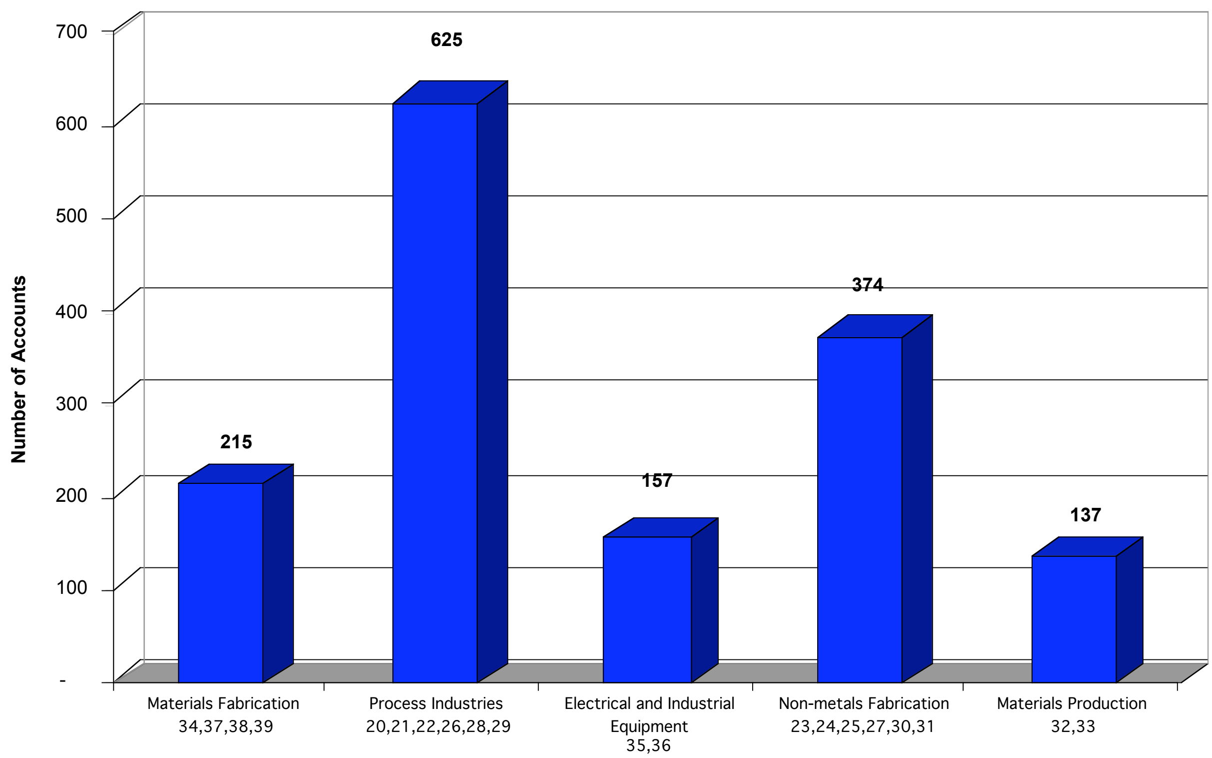
| SIC | Description | Number of Businesses <50 hp | 50-100 hp | 100-500 hp | >500 hp | Total |
|---|---|---|---|---|---|---|
| 34,37,38,39 | Materials Fabrication | 21 | 102 | 77 | 15 | 215 |
| 20,21,22,26,28,29 | Process Industries | 366 | 144 | 97 | 18 | 625 |
| 35,36 | Electrical and Industrial Equipment | 100 | 38 | 17 | 2 | 157 |
| 23,24,25,27,30,31 | Non-metals Fabrication | 293 | 54 | 26 | 1 | 374 |
| 32,33 | Materials Production | 27 | 37 | 58 | 15 | 137 |
| **Total** | | **807** | **375** | **275** | **51** | **1,508** |
| **Percentage** | | **54%** | **25%** | **18%** | **3%** | **100%** |

## Table 6: Number and Percentage of Total Compressed Air Horsepower by SIC Group and Size

| SIC | Description | Total Compressor Horsepower by Size Class | | | | Total |
|---|---|---|---|---|---|---|
| | | <50 hp | 50-100 hp | 100-500 hp | >500 hp | |
| 34,37,38,39 | Materials Fabrication | 1,013 | 6,927 | 14,873 | 19,197 | 42,010 |
| 20,21,22,26,28,29 | Process Industries | 11,551 | 10,020 | 18,802 | 17,851 | 58,224 |
| 35,36 | Electrical and Industrial Equipment | 2,949 | 2,491 | 2,907 | 1,188 | 9,535 |
| 23,24,25,27,30,31 | Non-metals Fabrication | 7,048 | 3,803 | 4,864 | 556 | 16,270 |
| 32,33 | Materials Production | 1,201 | 2,699 | 11,486 | 15,069 | 30,455 |
| **Total** | | **23,763** | **25,940** | **52,932** | **53,860** | **156,494** |

| SIC | Description | Percent of Compressor Power by Size Class | | | | Total |
|---|---|---|---|---|---|---|
| | | <50 hp | 50-100 hp | 100-500 hp | >500 hp | |
| 34,37,38,39 | Materials Fabrication | 1% | 4% | 10% | 12% | 27% |
| 20,21,22,26,28,29 | Process Industries | 7% | 6% | 12% | 11% | 37% |
| 35,36 | Electrical and Industrial Equipment | 2% | 2% | 2% | 1% | 6% |
| 23,24,25,27,30,31 | Non-metals Fabrication | 5% | 2% | 3% | 0% | 10% |
| 32,33 | Materials Production | 1% | 2% | 7% | 10% | 19% |
| **Total** | | **15%** | **17%** | **34%** | **34%** | **100%** |

## Figure 4: Number of Customer Accounts by SIC Group




Previous research found that few compressed air equipment suppliers target their marketing effort by industry type.[3] In this study, half of the suppliers indicated that they target their marketing by industry type (Q18)[4], but their targeted marketing tended to be with the intent of

[3] Seven percent, from *Compressed Air Systems Market Assessment and Baseline Study for New England, Aspen Systems Corporation, November 1999, p. 19.*
[4] "Q18" means interview question number 18.

selling specialized equipment. For example, one vendor targeted pharmaceutical companies and the beverage industry when selling oil-free compressors. A controls vendor targeted industries (unspecified) with multiple pressure requirements. As addressed in the recommendations, researchers believe that, among businesses with significant compressed air loads, industry type is not a significant indicator of compressed air system-wide efficiency opportunities. With the possible exception of the pharmaceuticals industry type should not be a key factor in any subsequent program design.

For the PSE&G sample of 25 customers, analysts compared compressed air horsepower to peak demand. The horsepower per peak kilowatt (hp/kW) was higher for large customers, 0.23 hp/kW, versus 0.07 to 0.17 for smaller customers, as shown in Table 7. Two interviewed customers currently face air capacity constraints,[5] meaning that the hp/kW ratio would be even higher if plant managers had all of the compressor capacity they feel they need. Two of the large interviewees use over 0.6 hp/kW.[6]

**Table 7: Customer Profiles by Size**

| Parameter | 50-100 hp | 100-500 hp | Over 500 hp |
|---|---|---|---|
| Average non-backup total compressed air horsepower (hp) | 61 | 223 | 1,457 |
| Average peak demand (kW) | 1,516 | 2,263 | 9,802 |
| Average compressor hp/plant peak demand | 0.07 | 0.17 | 0.23[7] |

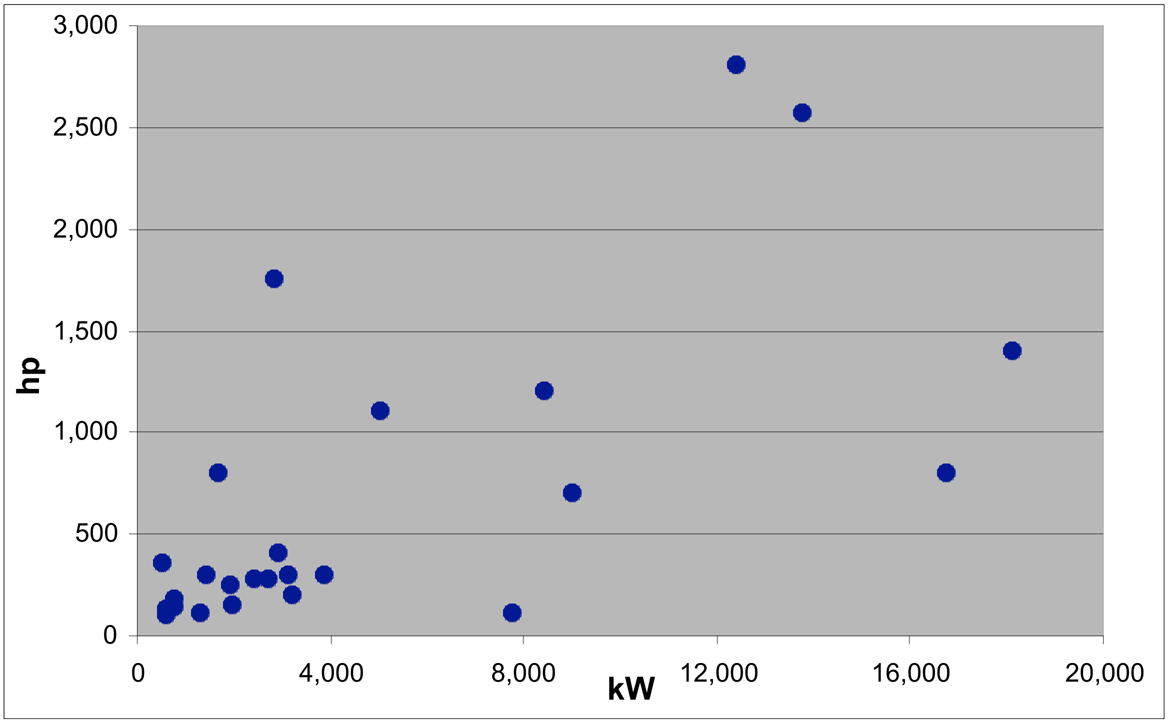
In absolute terms, PSE&G's larger customers use more energy for compressed air than smaller customers do. Two-thirds of the installed horsepower is in plants that exceed 100 horsepower. Larger customers also use a higher proportion of their energy for compressed air. And of course individual large customers spend more money on compressed air than do individual smaller customers. All of these results suggest that the initial program design should be targeted at larger customers. Though too small a sample to generalize, the very largest customers—those with over 1,000 compressor horsepower—have similar hp/kW ratios as 500-1,000-horsepower customers. More discussion on the influence of compressor plant size on operations can be found in Section 2.1.4.

When comparing this survey's results with results from prior studies the results are not sufficiently different to be significant. Table 5 shows results based on population data and use "percentage of energy to compressed air" data from a large study in Massachusetts. Using that data, the predicted overall hp/kW in the PSE&G territory is 0.12 hp/kW. In comparison, extrapolating the ratio from the 25 customers to the population results in an average proportion of 0.09 hp/kW.[8] Figure 5 illustrates the wide range of the hp/kW proportion. Because the

[5] These two customers might be good targets for case studies.
[6] For comparison, a plant that ran no other equipment than air compressors and ran them at full load would use about 1.2 hp/kW.
[7] One customer has two 1,150-hp diesel engine-driven compressors. This customer was excluded from the hp/kW calculation.
[8] Assuming customers under 50 hp have the same hp-to-kW proportion as the 50- to 100-hp stratum customers.

proportion varies so widely and the sample is small, the difference of 0.03 hp/kW is not significant.

**Figure 5: Compressor Plant Horsepower as a Function of Plant Peak Demand**




**Air loads.** As part of the interview process, the interviewers asked each compressed air plant manager[9] to name the end-use that required the maximum pressure at their facility. Table 8 summarizes their answers. No concentration of end-uses that could be leveraged in program design is evident.

**Table 8: Compressed Air End-Uses Requiring Maximum Pressure**

| | | |
|---|---|---|
| Presses (4) | Blast Machines | Oven |
| Palletizers (3) | Drawing Beads | Pneumatic Pumps |
| Bag House (2) | Dust Collectors | Paint shop |
| Production Line (2) | Extruders | Regrind Area |
| All the same (2) | Furnace controls | Valves |
| Air cylinders | Glass removal system | |

The average air pressure setting leaving the compressor room cycles or modulates between 87 and 105 psig. The standard deviation for the minimum, and maximum pressure and pressure range is under 12 psi for each.

[9] Facilities engineer, physical plant manager, maintenance foreman, plant engineer, or equivalent title for each site.

**2.1.2. Compressed Air Savings Potential.** Savings potential analysis allows PSE&G to decide whether the potential benefits of promoting efficiency of compressed air systems are attractive enough to justify proceeding with program strategies. Saving potential was calculated using the formula in Figure 5.

### Figure 5: PSE&G Compressed Air Cost Savings Potential Formula

$$\text{Savings Potential (\$/yr)} = \text{Region Total Industrial Demand (MW)} \times \text{8,760 (hr/yr)} \times \text{Avg. Facility Load Factor (\%)} \times \text{Facility Energy to Compressed Air (\%)} \times \text{Compressed Air Savings Potential (\%)} \times \text{Average Industrial Energy Cost (\$/MWh)}$$

The formula for peak demand savings potential is similar, as shown in Figure 7.

### Figure 7: Peak Demand Savings Potential Formula

$$\text{Savings Potential (MW)} = \frac{\text{Region Total Industrial Demand (MW)} \times \text{8,760 (hr/yr)} \times \text{Avg. Facility Load Factor (\%)} \times \text{Facility Energy to Compressed Air (\%)} \times \text{Compressed Air Savings Potential (\%)}}{\text{Average Compressor Motor Run Time (hr/yr)} \times \text{Compressor Motor Loading Factor (\%)}}$$

Each component of the two formulae is explained below.

**Region total industrial demand.** The sum of the annual peak demands for all industrial facilities served by PSE&G is 1,363 megawatts (MW), as shown in Table 9. The data are organized by general industry type and show total population and per-customer use.

### Table 9: Public Service Electric and Gas Industrial Population General Electric Use Statistics[10]

| | | Population | | | | | | | Per Customer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SIC | Description | Number of Businesses | Total Peak kW | Total Annual MWh | Load Factor | PSEG Revenue (thousands) | Percent of Customers | Percent of Energy | Peak kW | Total Annual kWh | PSEG Revenue |
| 34,37,38,39 | Materials Fabrication | 215 | 185,918 | 857,396 | 53% | $61,200 | 14% | 15% | 865 | 3,987,891 | $285,000 |
| 20,21,22,26,28,29 | Process Industries | 625 | 676,350 | 2,685,125 | 45% | $191,700 | 41% | 48% | 1,082 | 4,296,199 | $307,000 |
| 35,36 | Electrical and Industrial Equipment | 157 | 94,798 | 378,776 | 46% | $27,000 | 10% | 7% | 604 | 2,412,587 | $172,000 |
| 23,24,25,27,30,31 | Non-metals Fabrication | 374 | 247,488 | 1,062,498 | 49% | $75,900 | 25% | 19% | 662 | 2,840,904 | $203,000 |
| 32,33 | Materials Production | 137 | 158,612 | 647,363 | 47% | $46,200 | 9% | 11% | 1,158 | 4,725,281 | $337,000 |
| **Total** | | **1,508** | **1,363,166** | **5,631,159** | **47%** | **$402,100** | **100%** | **100%** | **904** | **3,734,190** | **$267,000** |

**Average facility load factor.** The average facility load factor is 47 percent.

**Facility energy use to compressed air.** Facility energy use to compressed air represents the portion of total facility energy use spent on compressed air. The New England Electric System (NEES) performed an in-depth study of industrial facility energy use in 1995. Overall, the NEES

[10] Revenue based on an average energy cost of $0.0714 /kWh for PSE&G industrial customers, as listed in *Energy User News,* May 1998.

study found that 9.4 percent of facility energy use is dedicated to compressed air.[11] Because this value varies substantially between industries, researchers used the percentages for each major industry group and recalculated the weighted average value for PSE&G. The relevant NEES and PSE&G data (taken from Table 4) and result (8.8 percent) are shown in Table 10.

### Table 10: Percentage of Facility Use to Compressed Air

| *Industrial Market Segment* | *PSE&G Percentage of Total Known Customer Load* | *NEES Percentage of Facility Energy to Compressed Air* |
|---|---|---|
| Metals Fabrication | 14.3 | 17.7 |
| Process Industries | 41.4 | 6.7 |
| Electric and Electronic Equipment | 10.4 | 7.9 |
| Nonmetals Fabrication | 24.8 | 5.1 |
| Materials Production | 9.1 | 15.2 |
| **Total** | **100%** | **PSE&G Weighted Average 8.8%** |

Interviews with customers produced different results. On average, the facilities engineers interviewed estimated that their compressed air plant energy costs are 10.4 percent of their total electricity bill (Q52). Because interviewee estimates were not based on site visits or calculations and because the sample size is small, researchers recommend using 8.8 percent as the better value.

**Compressed air savings potential.** Based on the meta-analysis of compressed air savings potential from four secondary sources and from supplier interviews, technically and economically feasible energy savings available from compressed air energy upgrades is estimated to be approximately 30 percent. Source data for this estimate are summarized in Table 11. Complete references for each source can be found in the bibliography.

[11] *The NEES Companies C&I Data Development Project – Market Profiles Report*, Regional Economic Research, 1995, p. 7.1.

### Table 11: Compressed Air Energy Savings Potential as a Percentage of Total Compressed Air Energy Use

| Estimated Energy Savings Potential | Source |
|---|---|
| 5–38 | Prospectus: Energy-Efficient Compressed Air Systems in Commercial and Industrial Facilities, Options for Regional Market Transformation, p. 17. |
| 20–50 | Improving Compressed Air Energy Performance: A Sourcebook for Industry, p. 1-1. |
| 35–71<br>49% average | Case Studies Compressed Air System Audits Using: AIRMaster Compressed Air System Audit and Analysis Software, p. 2 |
| 42–58 | Strategies to Promote Energy-Efficient Motor Systems in North America's OEM Markets: Air Compressor Systems, pp. 3, 57-58. |
| 5–50<br>28% average | New England Study (12 supplier responses) |
| 0-70<br>39% average | Supplier interviews for this project (Q34 plus Q36). Savings *available*. Eight responses:<br>0 20-40 15-50 35<br>35-70 45 55 55-65 |
| 10-50<br>24% avg. (under 100 hp)<br>27% avg. (over 100 hp) | Supplier interviews for this project (Q42). Typical savings *offered*. Responses:<br>Under 100 hp: 30 25-50 10-20 15-20 30 20-25 15<br>Over 100 hp: 30 NA 30-40 15-45 20 15-20 NA |

The estimates have a wide range, starting under ten percent and rising to 58 percent and averaging about 30 percent. Despite the wide range of the estimates, the majority of them are consistent with one another.

The AIRMaster estimate of 35–71 percent (the weighted average is 49 percent) is high compared with other estimates. It is based on the average savings potential of 17 energy efficiency measures identified for seven case studies. A single measure (reducing leaks sufficiently to eliminate use of a 300-hp compressor at a sawmill) constitutes 39 percent of the savings. Without this one measure, average savings are 29 percent. This set of case studies is not improbable and is a good tool for illustrating savings potential to end-users. In fact the researchers verified that the sawmill customer did in fact implement the upgrade and take the compressor off-line. However, researchers believe that the small sample size and large savings for one customer result in higher average savings potential than is appropriate for industrial facilities in New Jersey.

The Easton Systems OEM Report, which estimates 42 to 58 percent savings, also is high compared to other estimates. Analysts believe that this estimate overestimates savings potential because it assumes that all customers can save at least four percent in each of five categories: (1) Reducing system pressure through better design, (2) Reducing pressure through better operations & maintenance practices, (3) Reducing demand through better design/size supply to demand; (4) Reducing demand through better operations & maintenance practices; and (5) Improving supply conditions/equipment environment.

The interviewed New England and New Jersey suppliers consistently estimated savings in the middle of the range. Their answers varied more in the range of savings than the average.

In summary, researchers used a value of 30 percent as the average savings potential based on the above data and interpretation.

**Average industrial energy cost.** $0.0714 per kWh, previously cited.

**Average compressor motor run time.** The average compressor motor run time is the total hours per year that the motor is running. *The NEES Companies C&I Data Development Project–Market Profiles Report* (Figure 7–8), estimates average compressor operating hours in each of five compressor size classes. By weighting these data with data from Figure 7-9 on the same page of that report, the average annual operating time for compressors over 20 hp is 3,661 hours per year.

**Compressor motor loading factor.** The compressor motor loading factor is defined as the motor's average load when running divided by the motor's peak load when running. The average load when running can be the same as the motor nameplate load but is not necessarily so.[12] If it is assumed that the compressor motor peak load when running occurs at the time of facility peak load, then this factor can be used to convert compressor average demand savings to demand savings at the time of facility peak load. The calculated loading factor is 82.9 percent.

Researchers used unpublished motor loading factor data collected from site surveys of 250 air compressors in 1992 by the Oregon State University Energy Analysis and Diagnostic Center (EADC), now the Industrial Assessment Center. The load factors within each SIC are based on estimated load factors for individual compressors and are combined into a single factor weighted by compressor horsepower. The estimates were originally made based on a complete site survey with billing data reconciliation, and usually included spot current and voltage metering of large motors such as compressors. Compressor sizes ranged from 5 to 400 hp. To calculate the overall average load factor across SIC codes, analysts weighted the SIC-specific EADC load factors according to their occurrence in the PSE&G service territory, as shown in Table 12.

**Table 12: Compressor Motor Loading Factors**

| SIC | Description | Load factor |
|---|---|---|
| 20 | Food products | 71.7% |
| 24 | Wood products | 87.0% |
| 30 | Rubber and plastics | 83.2% |
| 34 | Fabricated metals | 86.4% |
| **Total, weighted by PSE&G proportions** | | **79.7%** |

By combining all of the factors into the formulas provided at the beginning of this section, the result is a total savings potential of $11 million per year and 51 MW, for an average of $7,000 per customer per year. The estimated 22 percent of industrial customers with over 100 hp in non-back-up compressor motors use 61 percent of the total peak demand and have 68 percent of the

[12] Compressor manufacturers typically design their systems so that the motor operates at 5 to 10 percent above nameplate brake horsepower at full load and design pressure. Plant pressure settings and other factors such as age affect actual motor maximum load.

compressed air horsepower and savings potential. The 317 larger customers have $7 million savings potential total, or about $23,000 each.

**Where is the waste?** Customers believe that an average of 68 percent of the total system energy and air waste is due to problems outside of the compressor room versus inside of it (Q50). In contrast, suppliers believe that only 42 percent of the waste can be eliminated by optimization services such as leak audits, controls, eliminating unnecessary use of compressed air; the remaining 58 percent of the waste can be eliminated through capital expenditures such as more efficient compressors and dryers (Q33-36). In addition, 42 percent of the suppliers believe that the majority of waste is due to distribution system problems rather than inefficient compressed air generation (Q32). The questions are not exactly parallel to one another, but the answers reflect conflicting perceptions. Though improving both distribution problems and part load control is required to maximize savings, based on the collective opinions of experts around the country and DOE Industrial Assessment Center data we believe that the customers' perceptions are more correct.

Suppliers were asked to specify and rank the biggest sources of waste they found in their customers' facilities (Q29-31). Their answers are shown in Table 13. The columns correspond to the three questions below and are labeled for mapping.

Q29 What are the three biggest sources of waste and inefficiency in existing compressed air systems?
Q30 Which is the single largest source of waste?
Q31 Which has the quickest payback?

### Table 13: Sources of Waste in Compressed Air Systems

| Source | Number of Times Selected by Suppliers (n=11) | | |
|---|---|---|---|
| | Q29 | Q30 | Q31 |
| Leaks | 8 | 5 | 4 |
| Excessive pressure in system | 6 | 2 | 4 |
| Oversizing plus poor part load control | 5 | 2 | 2 |
| Inappropriate use of compressed air | 5 | 1 | 1 |
| Poor compressor sequencing | 2 | 1 | 2 |
| Poor maintenance (filters, oil) | 2 | 1 | 0 |
| Poor distribution system design | 2 | 0 | 0 |
| Poor central plant design | 1 | 0 | 0 |
| Inefficient compressors | 1 | 0 | 0 |
| High pressure drop dryers or other inefficient auxiliary equipment | 1 | 0 | 0 |
| Other | 0 | 0 | 0 |

Leaks, excessive pressure in system, and poor part load control are all waste sources that can be eliminated without capital expenditures in the majority of situations. Suppliers' ranking of specific waste sources supports the customers' perceptions of waste sources more than their own contention that capital investment is necessary to eliminate waste. The conflicting results of the New Jersey suppliers probably reflect the difficulty of reconciling the traditional equipment sales mentality held by the majority of them with their technical understanding of the root problems.[13]

[13] For more general information on ways to eliminate compressed air waste, see *A Guidebook for Screw Air*

System-wide optimization is emphasized throughout this report as being critical to success. This is clearly illustrated by considering the emphasis on waste reduction outside the compressor room together with the third highest rated source of waste, poor part load control. Although much of the waste in a system may be outside the compressor room, if changes in the compressor room are not made at the same time as changes outside, there may be little or no savings. For example, a leak might have an estimated "cost" that is accurate, but after repairing the leak there may be no savings unless a compressor either shuts down or unloads more often in response to the change.

**Does size matter?** Interviewees were asked whether the overall percentage of waste increased, decreased, or stayed about the same as facilities get bigger (Q37). Overwhelmingly, the answer to this question was "increases." When asked what industries might see the highest compressed air potential, the results indicated that no particular sector stood out (Q39). All but one of the listed SICs were chosen once; none was chosen more than three times. More discussion on size-sensitive issues follows in section 3.1.4, Compressed Air System Management Characteristics.

**2.1.3. Air Compressor Population.** This section provides a profile of the typical interviewed customer's compressed air plant and then a distribution of total and individual compressor horsepower of all of the customers' plants to help PSE&G envision the size and types of compressor plants of customers likely to participate in subsequent programs. Table 14 presents average statistics of interviewed customers. Appendix A explains how the interviewees were selected from PSE&G's population of 51 large (predicted to be over 500 hp) and 266 small (predicted to be 100 to 500 hp) customers.

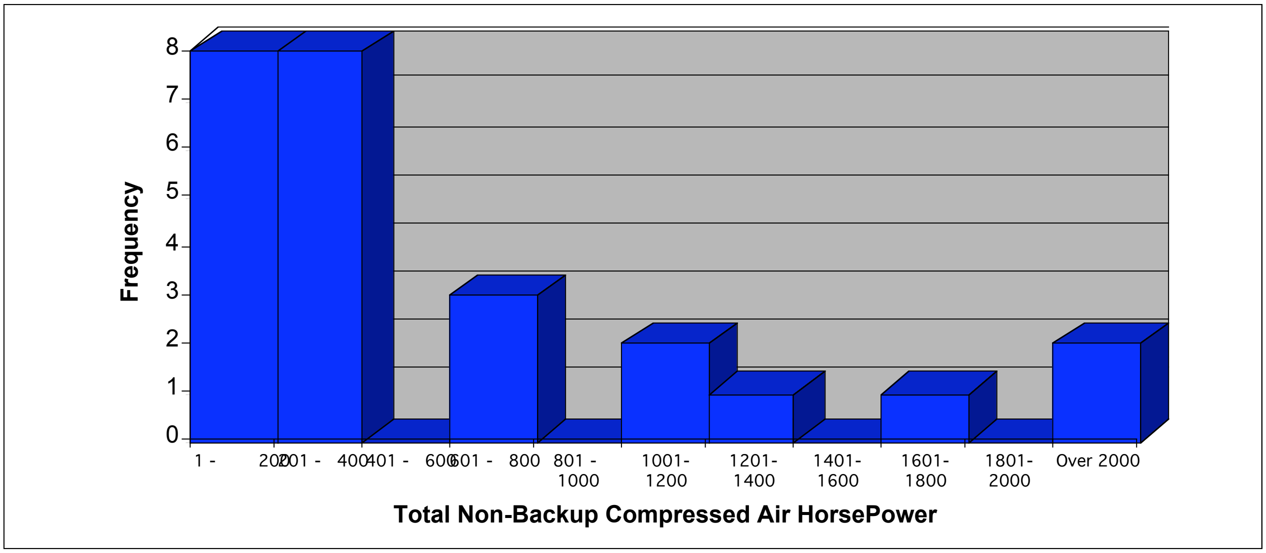
### Table 14: Average Interviewed Customer's Compressed Air Plant Characteristics

| Parameter | Value | |
|---|---|---|
| Facility peak demand | 4,977 | kW |
| Total non-backup compressor horsepower | 667 | hp |
| Backup horsepower | 233 | hp |
| Total number of non-backup compressors | 3 | |
| Number of backup compressors | 1 | |

*Compressor Controls: Operating Principles and Selection for Minimum Energy Use,* for Bonneville Power Administration, by Jonathan B. Maxwell, November 1992, pp. 35–41; *Industrial Compressed Air System Energy Efficiency Guidebook*, for Bonneville Power Administration, by Carroll Hatch & Associates, December 1993, pp. 13-1–13-4; *AIRMaster Compressed Air System Audit and Analysis Software Analysis Methodology*, for Bonneville Power Administration, by Compressed Air Specialist (G. M. Wheeler), January 1997, pp. 21–33; *Improving Compressed Air System Performance: A Sourcebook for Industry*, for U.S. Department of Energy Motor Challenge Program, by Lawrence Berkeley National Laboratory and Resource Dynamics Corporation, April 1998, Section 2.

All customers interviewed have compressed air plants under 2,300 hp excluding backup units. The median customer has 300 hp. The largest individual compressors in operation are 1,125-hp gas-driven and 700-hp electric units. The median customer has three non-backup compressors. Median individual compressor size including backup units is 150 hp. Five customers do not have any dedicated or rotated backup units. Figure 8 shows the distribution of compressor plant size of the interviewed customers.

**Figure 8: Distribution of Interviewed Customers' Total Non-Backup Compressed Air Horsepower**




**2.1.4. Compressed Air System Management Characteristics.** This section addresses system management issues by end-users that are not addressed in the metrics/baseline section. In summary, the impression left from the interviews is that of suppliers with traditional marketing methods responding to customers' basic operation needs. Facility staff buys compressors and services as needed from vendors, and they respond to compressed air system problems as they occur. There is little proactive planning or aggressive cost cutting. If compressed air experts are involved in the current business transactions at all, it is only through existing vendor-customer relationships.

**Maintenance.** Twenty-five percent of the customers have service contracts for at least a portion of their scheduled compressed air system maintenance. Sixty-seven percent of these contracts are with a vendor and 33 percent are with an independent contractor. The service itself varies considerably. Most involve preventive maintenance at a minimum; several involve leak detection, leak repair, power monitoring, and water trap inspection. None involve re-assessing pressure requirements or compressed air needs. Frequency tends to be one to three times per year.

Only one of the customers conducts comprehensive system assessments with employees and it appears unlikely that large numbers of customers will ever do so because of the specialized skills and practice required for such an assessment.

**Procurement.** Eleven customers reported purchasing new compressed air equipment in the past two years (Q28). The reasons cited for their decisions to select a particular product or vendor were as follows:

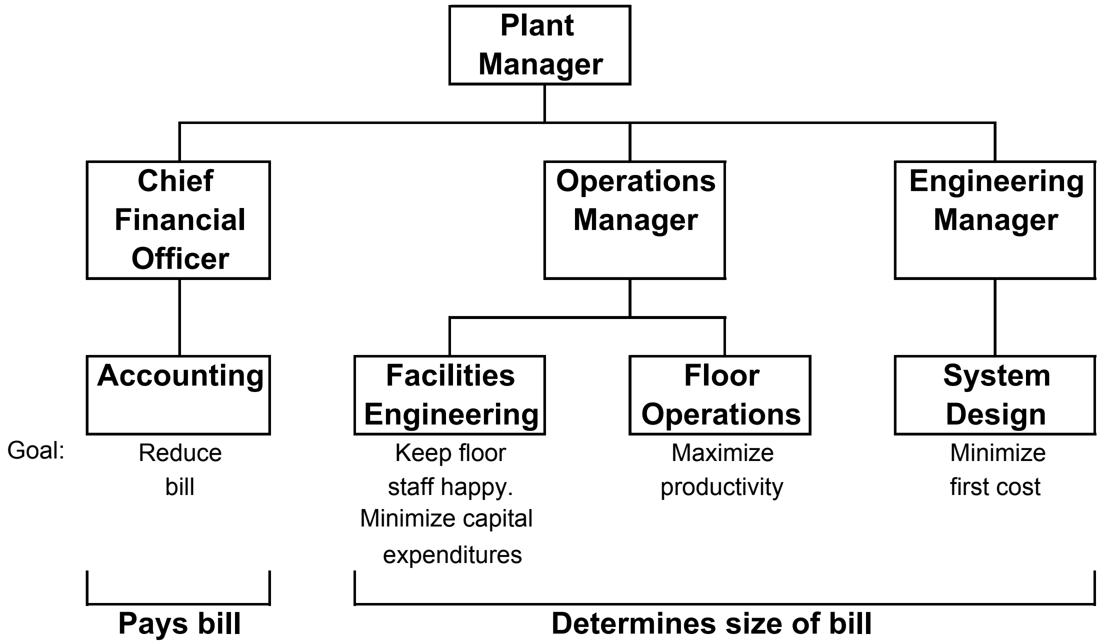
| *Reason* | *No. Respondents* |
|---|---|
| Selected same brand/vendor as already in plant | 7 |
| First cost | 2 |
| Efficiency Rating | 1 |
| Special type of equipment required | 1 |

This strong inclination to use precedent as a primary decision-making factor presents a significant barrier because only a few of the suppliers in the service territory demonstrated interest in system-wide optimization. This is discussed further in the Barriers section.

During the interviews with facilities engineers and managers, the expressed customer perceptions of the compressed air market structure were generally limited to conventional vendors. Only eight percent of interviewed customers cited entities other than internal staff or their vendor as the first person they think of "when some part of the compressed air system other than the compressor needs to be replaced or upgraded" (Q49).

**Decision structure.** Both suppliers and end-users cited the difficulties of gaining management endorsement of compressed air investments that reduce electricity expenditures. Figure 8, the End-User Typical Management Structure, illustrates why gaining support can be difficult. The structure generally applies to customers over 500 kW interviewed in this study. Smaller customers may have a more consolidated structure. Unless the end-user operates under a detailed cost-accounting structure, utility bills are typically considered an unmanaged overhead expense. Those individuals that control energy use are not responsible for paying the bill. This represents a barrier to investing in energy savings projects in general, not just in compressed air projects. The accounting department pays the bills from the overhead budget, but the engineering and operations departments that control use make decisions that may ignore or even contradict electricity reduction goals. An approach that one supplier uses to overcome this barrier is that he refuses to proceed with a full proposal until he has met with representatives of all four entities shown on the lower level of Figure 9 at the same time. This is an aggressive position that not all traditional compressor vendors may be able to take, but the supplier that uses the approach endorses it entirely.

### Figure 9: End-User Typical Management Structure




**Management differences as a function of size.** Small and large customers manage their compressed air systems differently from one another in certain respects. Notable differences are listed below:

*Compressor type.* As would be expected, only large end-users run centrifugal compressors. Otherwise, compressor type is similar, with the majority being twin-rotor screw units and the next most frequent being reciprocating units. Also as would be expected, large end-users were three times as likely to use a multi-compressor control system. Smaller customers were almost twice as likely to use the less efficient but more convenient modulation-only form of part-load control.

*Maintenance.* Two-thirds of large end-users performed their own major preventive maintenance, compared with only one-fourth of small end-users. Almost all customers perform their own minor routine maintenance.

*Reducing air loads and optimization studies.* Forty-four percent of large end-users either installed engineered nozzles or eliminated air-using equipment in the last two years, compared with 23 percent of small end-users. Furthermore, large customers were almost four times more likely to have conducted an optimization study. These two examples indicate a significant difference in behavior regarding compressed air management.

*Estimating the portion of the electric bill for compressors and related equipment. (Q52)* Small and large customers both estimated that 10 percent of their billed energy use is for compressed air. Their answers were the same but their accuracy was not. Ten percent correlates fairly well with small customers' estimated use of 12 percent but significantly underestimates large customers' estimated use of 18 percent based on reported horsepower and utility bill data. This underestimation should be a point of emphasis in any training.

*Many management issues are the same for small and large customers.* Pressure settings are virtually identical for small and large customers. Just over half of each group can estimate their monthly energy bills. None of the interviewees had attended any formal compressed air training; however, at least 78 percent of them expressed interest in training, depending on the topic. These last two findings highlight potential training opportunities.

**How to reach facilities engineers.** When interviewees were asked where they would be most likely to see advertisements of a compressed air-related service for their utility (Q61), their answers were:

- Direct mail, 96 percent;
- Utility bill insert, 4 percent; and
- Local or national trade journal or newsletter, mass media, or other, 0 percent.

Most facilities engineers do not see bill inserts because paying energy bills is not their responsibility. Direct mail only will work if addressed sufficiently to arrive at the facility engineer or equivalent's desk.

## 2.2. Characterization of Market Structure and Delivery System

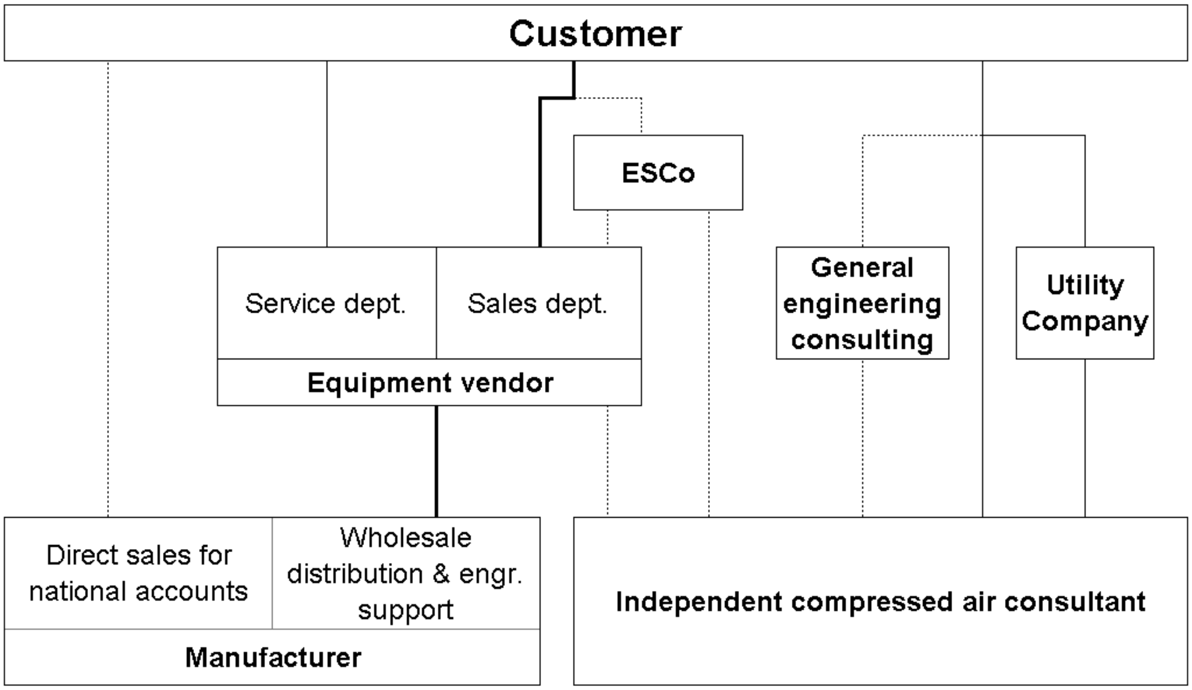
The previous section focused on end-user characteristics; this section addresses the compressed air equipment and services market structure and barriers to facilitating more system-wide optimization services.

In general, the supplier side of the market is sharply split into two distinct philosophical camps: Those that see the energy savings potential from system-wide analysis, and those committed solely to traditional equipment sales.

**2.2.1. Delivery Channels.** A significant majority of customers have long-term relationships with a single compressed air equipment vendor; 25 percent have service contracts with them, and most of the rest call in their vendor is needed. The market for independent consulting is limited. Only eight percent of customers have directly hired compressed air experts. Vendors report that a small market exists for energy service companies (ESCos). Manufacturers provide direct sales to a small number of national accounts. The more progressive suppliers subcontract to expert consultants under certain circumstances. Traditional equipment sales vendors decline to provide advanced system-wide study.

Figure 10 illustrates the flow of services between customers and suppliers and among suppliers. By far the strongest relationship is between the customer and the traditional vendor.

**Figure 10: Compressed Air Service and Equipment Supply Channels**




All interviewed suppliers provide some type of compressed air equipment to their clients. Only one of the companies does not provide any additional services, although several suppliers' services are quite limited. The compressor remanufacturer provides only remanufacturing and repair of reciprocating compressors. Half of the suppliers provide additional products other than compressed air equipment and services.

ESCos have not been active in compressed air projects in New Jersey. Three suppliers had limited involvement with ESCos resulting in eight or nine projects or bids in the last two years. Suppliers specifically cited the difficulty of generating balanced "apples-to-apples" comparisons to prove savings for guaranteed savings contracts.

Ingersoll-Rand is unique among manufacturers because they sell compressors and related equipment to customers through a network of company-owned vendors. Because it is not a true factory-direct relationship, and because vendors typically only sell one brand of air compressor, the arrangement is functionally similar to that of other vendors with separate central manufacturing and regional sales companies.

Interviewers asked all suppliers if they sold or were familiar with demand expanders[14] (Q54). Half of the interviewees were not familiar with any of the products listed in the survey. Two of the remaining suppliers actively market these products and a third mentions the process as a possibility in sales discussion. There was one company representative that disapproved of one

[14] Demand expanders, also called flow controllers, are devices that, in conjunction with large receivers, can reduce part load losses through smart pressure regulation. Three brands are ConserveAIR, XpandAIR™ by Zeks, and XCEED™ by Honeywell. Zeks and Honeywell's demand expanders are the same products with different nameplates. Honeywell sells their devices directly to users; ConserveAIR sells through intermediate market participants.

demand expander product listed in the survey, but this was a vendor that sold one of the products and disapproved of his competitor's design. The ConserveAIR demand expander had the widest range of interviewee response of any of the products, ranging from endorsement to unfamiliarity.

From the results of this survey, it appears manufacturers of demand expanders have a challenging task in convincing suppliers and customers that these products are effective. As with guaranteed performance contracts, rigorously quantifying savings is difficult. Case studies are likely to be the most marketing persuasive tool.

**Supplier advertising.** A majority of the suppliers (75 percent) use some form of advertising and marketing; the remaining suppliers expend no effort in this area. The three most common techniques for marketing are training seminars (67 percent), follow-up calls (58 percent) and trade shows (45 percent). The most common approaches to advertising are maintaining a web site (50 percent), calling prospective customers (50 percent), advertising in trade journal (45 percent), and direct mailings (45 percent). Other techniques for advertising cited by survey respondents are maintaining a toll free telephone line, advertising in the yellow pages, and obtaining subcontracts from competition (Qs 15-17)

**Non-energy benefits.** When asked about the non-energy benefits of upgrades primarily intended to save energy dollars (Q41), the most common benefit cited was having more reliable equipment (58 percent). Other answers in the order of most common to least common are having:

- Longer lasting equipment,
- Smoother pressure supply,
- Oil-free air,
- Dryer air,
- Extended warranties,
- Redundancies,
- Quieter operation, and
- No benefit.

This topic is addressed further in Section 2.3.2, Progress Indicator 5, Supplier Marketing of System-wide Energy Efficiency Services.

**Current opportunities for compressed air system optimization services.** In today's market, both customers and suppliers have an abstract sense of the amount of waste in compressed air systems. Furthermore, they clearly understand that the majority of system waste stems from flaws in system distribution, control, and end-uses. Still, it is rare for either party to initiate service agreement to eliminate this waste for complex reasons involving economic and non-economic forces. Any utility company program that aims to change this dynamic is fighting against an entire culture of today's market conditions. Energy costs generally are not the facility engineers' responsibility. Facilities engineers react to compressed air delivery problems and suppliers react to facility engineers' expressed needs. Yet opportunities for compressed air system optimization services do exist.

When customers decide they need to purchase new compressors, either as replacement units or for expanded capacity, it is rarely a true crisis. Because most customers have excess capacity in the form of backup or oversized compressors, there is time to assess system needs. It is a time when many normal barriers to optimization can be overcome. The customer's upper management already is willing to commit to a capital outlay. The facility engineer is willing to invest the time necessary to think about the problem, and the supplier is facing the firm prospect of sales, so he is willing to invest in the prospective transaction. Customers can be educated to seek optimization services at that time. If one vendor offers the service and another does not, the first vendor gains a competitive advantage. If demand exists, eventually all the vendors will be motivated to provide and promote services as a competitive tool, even if they fear reduced compressor sales.

**2.2.2. Relative Activity by Delivery Channel.** To summarize the level of activity for system-wide services, three of the eight interviewed vendors are willing and capable of providing such services either by themselves or with subcontractors. The three progressive firms share three common traits:

1. They are larger than their competitors,
2. They conduct business both in New Jersey and outside the state, and
3. They have been or are currently affiliated with nationally known compressed air experts.

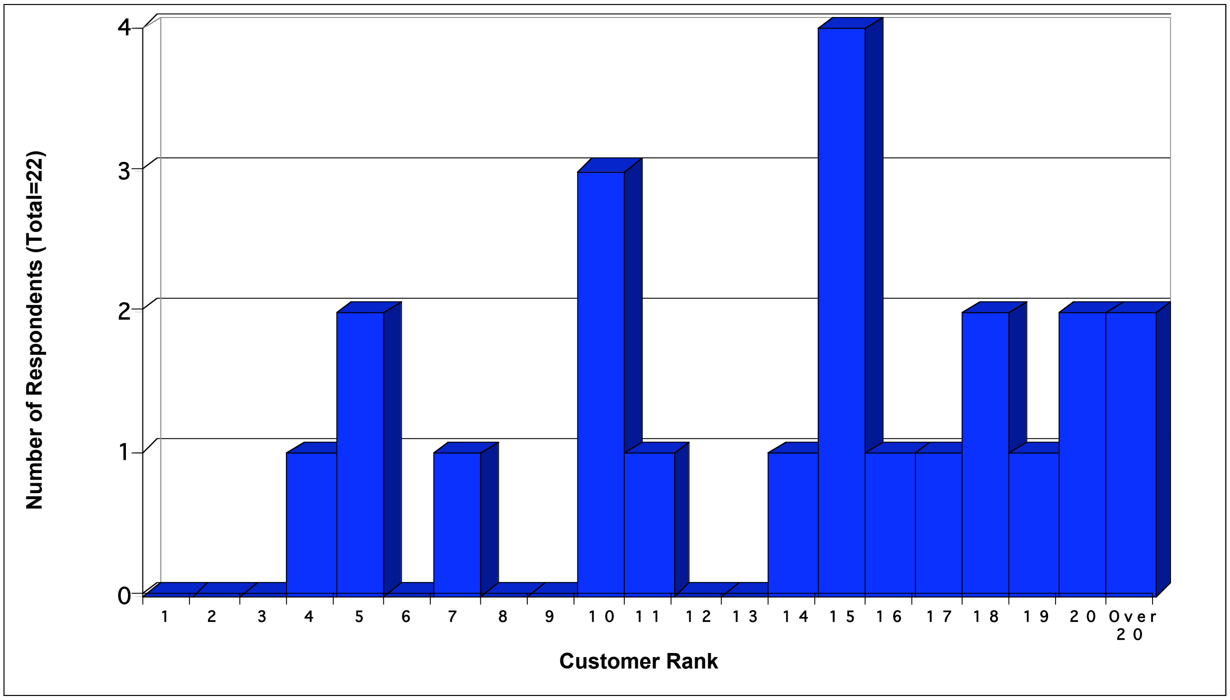
The three vendors left the impression, however, that the majority of their business remains traditional compressor equipment sales. Based on supplier interview recruitment efforts and secondary referral information, researchers estimate that about a half-dozen non-interviewed vendors sell industrial compressors and systems in the service territory. Most of them are believed to be smaller vendors that do not emphasize a systems-based approach. Including the five interviewees, there are an estimated total of eleven such vendors. The demand expander firms are in their own words "making a decent living," but only a portion of that business comes from New Jersey customers. New Jersey alone does not have enough activity to support demand expander business. Aspen found no independent compressed air consultants or references to any consultants that base their business solely on serving customers in New Jersey.

The vendors on the supply side of the market are not broadly qualified to deliver system-wide compressed air upgrades because there are too many vendors unwilling to learn or subcontract such services. However, there is a strongly committed segment of the supply side of the market that would welcome support from PSE&G.

**2.2.3. Barriers to Desired Transactions.** This section presents an overview of the barriers to increasing transactions related to compressed air system efficiency and then presents a more detailed review of specific barriers.

**Overview.** The best indication of barriers to increasing sales transactions and O&M activity related to system-wide compressed air efficiency is the answer to customer survey question 73. "If you had to rank your top 20 priorities today, where would managing compressed air costs fall in the ranking, if in the top 20 at all?" Figure 11 shows their answers.

**Figure 11: Rank of Compressed Air System Management in Facility Manager's Priorities**




The fact that end-users rank compressed air management an average of 13th on their priority list (assigning a value of 25 to the "over 20" responses) is a major barrier. More importantly, it is a manifestation of other barriers. End-users don't realize how much waste is in their systems and how cost-effective it is to eliminate it. Suppliers are not educating them otherwise. Certainly for some businesses compressed air efficiency does not affect profit compared with other concerns.

Customers were asked directly about barriers in Question 72 when they were asked to identify and rank the three strongest obstacles to increasing the priority given to compressed air systems efficiency maintenance in their industry. Table 15 summarizes their answers.

**Table 15: Customers' Strongest Obstacles to Increasing Priority Given to Compressed Air Systems Efficiency Maintenance**

| Obstacle | Number of Citations (First Choice) |
|---|---|
| Floor users don't realize how expensive compressed air is | 19 (5) |
| Payback times are too long | 18 (11) |
| Can't interrupt 24/7 operation | 10 (4) |
| Inertia/Ain't broke don't fix it | 9 (1) |
| Not a big cost for my operation | 8 (1) |
| Lack of time for engineer (downsizing) | 6 (0) |
| Lack of upper management support for cost-cutting investments compared to Expanding production or R&D (no capital available) | 5 (2) |
| Lack of training to identify problems or estimate savings | 5 (0) |

Suppliers were asked directly about barriers in question 22. "Why do customers not purchase more compressed air energy efficiency upgrades?" Table 16 summarizes their answers.

**Table 16: Suppliers' Perception of Customer Barriers to Purchasing Compressed Air Energy Efficiency Upgrades**

| Barrier | Number of Citations |
|---|---|
| Don't have available capital | 6 |
| Unaware of magnitude of savings | 5 |
| Payback times are too long | 3 |
| Don't care/stubborn/fear of unknown | 3 |
| Unaware of opportunities | 2 |
| Don't trust supplier savings claims | 2 |
| Need executive involvement | 2 |
| Other - Four other supplier-cited barriers were each mentioned once | 1 |

The list of barriers is long. One common theme emerged from their answers. Both believe that payback times are too long. Based on the opinions of compressed air system experts around the country, this is a misguided concern, at least in part. Much of the savings available from compressed air upgrades can be achieved without capital investment, or with investments that pay for themselves in less than two years. Presuming this is true, the real barrier is not actually long payback times but a lack of education about opportunities, their low cost, and their fast payback times. Customer responses cited elsewhere in this report show that they have a strong interest in training that would help overcome this barrier.

Other significant barrier-related themes found in either but not both of the sets of responses are that compressed air efficiency projects are not worth the trouble (voiced by customers) and that customers don't understand the opportunities (voiced by suppliers, and to a lesser extent customers). Within their own businesses, suppliers do not see barriers, although their responses indicate barriers exist. Most suppliers expressed a willingness to sell system-wide energy efficiency. On average, services are as profitable as equipment sales, if not more so (Q47), making the expansion of services an attractive option. Compounding all of the barriers is the fact that staff responsible for compressed air plant operation typically are not accountable for utility bills. Therefore they are not inclined to initiate time-consuming energy-saving projects until they are faced with a major project funded from their own budget or staffed from their own labor pool, such as buying an additional compressor.

**Specific barriers.** The rest of this section addresses specific barriers according to the stages of progress and implementation of Figure 2. They are based on both the answers to the two questions above and to open-ended discussion. Recommendations to overcome these barriers follow in Section 3.

### Barriers That Impede Recognition of Savings Potential

*Lack of customer education.* If customers are better educated about the possibilities of compressed air energy efficiency products, services and strategies, many of the vendors believe they can increase their sales. Customers report eagerness to eliminate this barrier by attending seminars or alternative training, which is an excellent first step. Suppliers agree that customers must be educated to before they will purchase compressed air optimization services.

The most commonly cited barrier by the facilities staff is that air users need education on the expense of compressed air. Because centralized training is impossible for this audience, providing videos or conducting in-person meetings with floor supervisors would be best to educate this group.

*Lack of supplier commitment to system-wide optimization.* New Jersey suppliers seem to fall into two distinct categories regarding system-wide efficiency opportunities. The majority of suppliers do not believe that customers are interested in buying anything other than compressors and are disinclined to adjust their business model otherwise. A minority of suppliers is more progressive; they either actively promote the system-wide optimization concept or are willing to do so. As addressed in the recommendations, the best PSE&G program returns are likely to come from nurturing suppliers who have expressed interest in system-wide optimization. It is more difficult to fight this barrier directly and change the entire belief set of suppliers who are committed to only traditional compressor sales.

*Customer lack of motivation.* Without a sense of urgency, the "if it's not broken, why fix it" mindset will not be overcome and few optional optimization projects will be implemented. Both customers and suppliers acknowledged this as a less significant barrier. The most practical way to eliminate this barrier is to avoid it: Present optimization solutions to customers when they think they need a new compressor, and have budgeted for one.

### Barriers That Prevent Supplier System-wide Service Product Development

For the majority of traditional vendors there is a lack of commitment. This is due partially to a lack of technical knowledge and also due to the belief that customer interests are elsewhere. No other barriers that prevent supplier system-wide service product development were identified.

### Barriers to Management Support for Compressed Air Upgrades

*Lack of available capital.* Lack of available capital appears to be a misguided concern of suppliers. Although it was cited by half of the suppliers as a barrier, no customers mentioned it as a barrier, other than in the context of long payback time.

*Lack of upper management support.* This is a minor barrier. Customers identified a lack of management support for compressed air and other energy-related upgrades as a barrier to implementing projects only 20 percent of the time. Instead, comments were made that upper management pushes for ways to reduce operating costs, including increased energy efficiency. Projects will generally be approved when projects promise paybacks of less than two years.

### Barriers to Marketing

*Standardized performance testing.* The seven customers who had purchased compressors in the past two years were asked whether they experienced difficulty with product comparisons (Q33) and whether it would be easier "to have a standardized efficiency rating system like the yellow labels on home appliances" (Q34). While only 25 percent of those that answered found comparisons difficult to make, 80 percent indicated that such labeling would be helpful.[15] This finding suggests that PSE&G should require suppliers to supply CAGI specification sheets prior to equipment incentive approval and that PSE&G educate customers about the availability of the specification sheets in training.

### Barriers to Selling and Implementing System-wide Upgrades

*Required payback time is too restrictive.* Compressed air system upgrades tend to be competitive when compared with other energy-efficiency measures in terms of payback. However, maximum payback periods of one and two years are common in today's industrial sector. Even with compressed air upgrades, recovering costs within two years can be difficult in some circumstances.

*Cannot stop a 24-hour per day, 7-day per week operation.* Comprehensive compressed air energy audits may require "breaking pipe" to measure flow or other parameters. When new hardware is installed or leaks are plugged, portions of the compressed air line must be shut down. However, at continuous operation facilities this may not be an option. When plants shut down for a week only once or twice a year, optional upgrades are likely to receive lower priority than critical repairs or expansion. Although customers stated this barrier, it is surmountable without undue difficulty in most circumstances.

*Always buy from the same vendor.* Customers cited precedent as a major factor when choosing between vendors. If the incumbent vendor is progressive, then the prospects for a system-wide study are greater. If not, breaking the cycle is a barrier. Standardized audit services endorsed by PSE&G might encourage otherwise hesitant buyers to explore alternative suppliers. Standardized

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[15] As part of a prior study, researchers interviewed David MacCullough, a consultant to the Compressed Air and Gas Institute (CAGI), who has served on the CAGI standards committee. Mr. MacCullough explained that "in the last few years" all current CAGI members that manufacture compressors began using CAGI standardized tests to develop performance data for their publications. The comprehensive ASME PTC-9/10 test is required for each new compressor design, the less expensive PN2CPTC1/2/3 is required for every manufactured unit. Recently, CAGI has been working with DOE Compressed Air Challenge staff and manufacturers to persuade them to publish performance data in standardized data sheets that can be included in the *CAC Sourcebook for Industry*.

efficiency ratings systems would help surmount this barrier as well.

## 2.3. Establishment of Metrics and Baseline Market Status

Metrics are used to assess current natural market conditions to later gauge the success of intervention. The supplier and customer questionnaires included questions asked for the first time in this study and tabulated in this report for comparison with answers to the same questions in later years. Change in answers should indicate change in market behavior. Later evaluators can estimate the portion of change due to utility market intervention. The metrics score the current market receptiveness and action in the compressed air energy efficiency market by rating:

- Vendor-reported activity related to energy savings and reported demand for such products;
- Customer awareness of the cost of compressed air and self-reported purchases of related optimization services; and
- Customer air compressor power requirements relative to over-all production.

As described in the introduction, end-effect indicators directly illustrate efficiency-related sales and system improvements. Progress indicators measure intermediate progress towards the desired end effects.

In this report, supplier data are reported as the percentage of respondents that answered each question. Because a single instrument was used for vendors, consultants, and manufacturers many questions were answered by only a portion of the interviewees. For certain interviews, time was limited and not all questions were asked. Customer interview results in this section are reported including population weighting.

**2.3.1. End-Effect Indicators.**[16] End-effect indicators directly measure market transformation. A successfully transformed market will have sellers offering, customers buying, and customers internally performing the desired end-effect indicators without utility company intervention.

[16] The questions selected as indicators were based on the *Metrics Report* (8/23/99) and then expanded after *Compressed Air Systems Market Assessment and Baseline Study for New England* report review.

***Indicator 1: Frequency of sales transactions involving high efficiency services and hardware Score 1[17]:***

| 1 | **2** | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| | ▲ | | | | | | | | |
| Major equip. only.<br>Few transactions.<br>React to problems. | | | | | | | | System-wide studies.<br>Many transactions.<br>Proactive search for opportunities. | |

The market is not active when compared to the number of financially viable opportunities. Customers do not seek out system-wide efficiency studies. The staff responsible for compressed air plant operation are not accountable for utility bills, are not inclined to initiate time-consuming projects without a crisis, do not believe financial returns are sufficiently attractive, and lack technical expertise. The majority of suppliers do not promote system-wide efficiency services proactively. Instead, they concentrate on traditional needs such as replacing compressors. Those that do promote such services have limited success within the service territory. If dedicated to such business they must operate out-of-state as well to keep business levels high.

Based on anecdotal information analysts believe that the level of activity is comparable with that found nationwide. The leading suppliers in PSE&G's service territory are among the leaders nationwide. But the average supplier is far from making a business from a system-wide approach. Customers' perceptions are generally that improvements just cost too much. Compressed air management is low on their priority list.

The immature state of the market for energy efficiency is most dramatically illustrated by the fact that none of the interviewed customers that reported buying new screw compressors said they bought efficient controls.

The reported increase in activity by customers was attributed by suppliers to the fact that customers had more knowledge and that there are now better technologies available to them. Answers to relevant questions follow:

Are suppliers selling and customers buying services and products to improve system efficiency?

| | |
|---|---|
| [Key] Customers that have had a compressed air study in the last two years. Q39. | 12% |
| [Key] Number of projects with receivers installed to improve part load performance that were not part of compressor sale, per supplier. Q14. | 0.5 |
| [Key] Number of system optimization projects performed by suppliers | 0.5 |

[17] The Score is a subjective rating of the over-all market status. It reflects Aspen's opinion of market maturity based on interviewee answers to both quantifiable and open-ended questions as well as observations made during site visits. The Score is not quantitatively replicable. "[Key]" parameters are particularly important, repeatable, replicable, statistically weighted (if customer) answers that directly measure the end-effect in question. Selection of [Key] parameters could change as the market evolves. Other parameters are repeatable, replicable, statistically weighted answers that indirectly measure an indicator or directly measure supporting evidence of an indicator.

| | |
|---|---|
| under subcontract to energy services providers, per supplier. Q21.[18] | |

Are customers buying efficient central plant equipment?

| | |
|---|---|
| Vendor estimate of percentage of their screw compressor sales with multiple-compressor automatic sequencing controls. Q13 | 40% |
| Vendor estimate of percentage of their screw compressor sales with modulating-only control. Q12. | 44% |
| Customer screw compressor purchases with modulating-only control. Q32. | 100% (n=5) |

General indicators of efficiency-related market activity:

| | |
|---|---|
| Have suppliers' customers been more or less active investing in energy-saving upgrades in the last two years? Q64. | 82% more<br>9% less<br>9% same |
| Typical savings offered by suppliers, to customers over 100 hp. Q42. | 27% |

***Indicator 2:*** ***Customer frequency of operations and maintenance activity to maximize system efficiency***

***Score 2:***

| 1 | **2** | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| | ▲ | | | | | | | | |

Fixed leaks as identified or not at all.<br>Leave pressure as is or increase it.<br>No preventive maintenance.

Routine leak repair.<br>Decrease pressure.<br>Preventive maintenance.

Compressed air system optimization is not a one-time packaged product. Systems are not static. Air-using equipment is added, removed, or repositioned in the plant. Pressure requirements change, water traps fail, leaks sprout, and nearly all of the hardware needs routine maintenance or repair. Implementation of recommendations from a compressed air system-wide study may optimize performance for a brief time but will only have a lasting effect if plant staff, including floor employees, follow preventive maintenance procedures and measure system performance regularly.

In this survey and elsewhere experts have identified excessive pressure, leaks, and inappropriate application of compressed air as three of the biggest sources of waste. In many cases customers can address these problems as part of their ongoing operations. In the survey, the only technique customers reported using to find leaks was to listen for them. No use of ultrasonic detectors, soap and water, interim pressure monitoring, or other methods were mentioned.

During interviews, customers answered direct questions about leaks and shared their other practices in open-ended discussions. There were a relatively high number of instances in which

[18] This question was supposed to be answered without regard to energy service provider subcontracting relationships but was misplaced in the instrument flow. In the future the question should be posed generally.

customers had installed nozzles or eliminated air end-uses, but few of them perform routine energy-saving operations and maintenance (O&M) procedures such as leak identification and repair. On average, there was no net pressure reduction among customers because one of the three that had changed pressure had to increase it by 20 psi due to installation of a new high-pressure piece of equipment.

Percentage of customers that

| | |
|---|---|
| [Key] Routinely check for leaks. Q12. | 7 % |
| Check for and repair leaks when leaks are found. Q11d-Q12a. | 56% |

Percentages of customers that have, in the past two years:

| | |
|---|---|
| [Key] Installed engineered nozzles or eliminated any compressed air end-uses. Q38. | 23% |
| [Key] Decreased pressure of air leaving the compressor plant. Q25.<br>Increased pressure of air leaving the compressor plant. Q25. | 7%<br>5% |

***Indicator 3: Supplier capability of delivering comprehensive energy efficiency services*[19]**
***Score 3:***

| 1 | 2 | **3** | **4** | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| Market void of capability. | | ▲ | | | | | | Capable, experienced, could absorb growth. | |

Three of the vendors and the consultant interviewed have the in-house expertise or affiliations with experts necessary to deliver compressed air energy efficiency services. That is more than enough to meet today's weak market demand. On average, these three vendors are larger than other vendors. Due to their large customer base, if they become broadly successful at selling comprehensive efficiency services the potential for the momentum to drive the entire market to buy and sell them exists.

If the market for system-wide efficiency services were to expand rapidly, and if optimization studies became a routine exercise as part of the compressor procurement process, suppliers would not immediately be capable of meeting demand. In addition, when asked, "In general, what is your opinion regarding the capability of New Jersey compressed air service providers to deliver optimization services?" (Q38), suppliers' views of their peers were not high. Of the nine suppliers that answered, only one indicated the capability of the service provider community - as a whole - was "very good." The rest of the suppliers indicated service provider capability as "poor" to "good" with middle ratings of "fair to good" and "okay, basically capable." This mediocre scoring of the suppliers by the suppliers is not a confidence-inspiring assessment of their abilities to promote or identify energy efficiency throughout the PSE&G territory.

The answers for this part of Indicator 3 are based only on the portion of suppliers who can offer

[19] Capability could be classified as a progress indicator, particularly the category of supplier product development, but it plays such a direct role in successful implementation of projects and discovery of new project opportunities that it is scored as an end-effect indicator in this report.

the item. For example, the consultant is not counted in the total when computing the percentage of suppliers that sell high-efficiency equipment. Vendors are considered eligible to offer optimization services.

The score is greater than three because some of the suppliers are completely capable of delivering comprehensive system-wide energy efficiency services and are even renowned for this. The score is not higher because the individual expertise does not necessarily extend throughout the entire company and because they represent the minority of suppliers. The majority of the supplier market fails to aggressively sell system-wide efficiency.

The data on the percentage of suppliers that offer efficiency-related services suggests that the majority of suppliers are capable. There are two reasons that evaluators have discounted this data in the Score. Most importantly, according to suppliers themselves the quality of services delivered is only marginal. A reported product or service offering does not necessarily constitute routine practice and high quality. Also, based on responses of suppliers that were contacted and not interviewed and discussion with interviewees, virtually all of the aggressive efficiency-related service providers were interviewed in this study, while many of the non-interviewed suppliers offer little or no such services.

Percentage of suppliers that offer efficiency-related services and contracts

| | |
|---|---|
| Energy audits (fixed fee). Q2. | 58% |
| Power metering (at least short term, not just spot metering). Q2. | 58% |
| Flow metering. Q2. | 58% |
| Leak detection (not part of audit). Q2. | 58% |
| Consulting Services (fee for service) | 58% |
| Energy audits (free). Q2. | 42% |
| Leak repair Q2. | 42% |
| Guaranteed savings. Q2. | 8% |

Other

| | |
|---|---|
| Have special techniques to promote energy saving services or products Q27 | 58% |

**2.3.2. Progress Indicators.** Progress indicators measure market transformation indirectly by tracking interim points through which the market must pass before reaching the desired condition. Before the compressed air market evolves into one that routinely makes system-wide upgrades, both customers and suppliers must recognize the savings available (or be willing to attend appropriate training), suppliers must have services to sell, and suppliers must actively promote those services. Progress indicators show the importance of intervention to overcome the progress barriers before attempting to simply change end-effects with cash incentives. The recommendations in this report will help the market mature and progress through all of the stages.

In aggregate, the progress indicators consistently support the end-effect indicators. Progress indicators show that the market for compressed air efficiency services is only part way through the first stage shown in Figure 2. The reason it has progressed only to this point is because suppliers do not believe customers will buy such a product. Customer responses support this belief. Cutting compressed air energy costs simply is not a high priority for most customers. However, customers are eager to receive training on the topic; this indicates PSE&G's initial market transformation opportunity.

***Progress Indicator 1: Awareness of system-wide costs and savings potential***

As noted in Section 2.1.2 Savings Potential, "Where is the Savings," both suppliers and customers demonstrated very good general understanding of the sources of waste, if not necessarily how to eliminate them. The majority of customers can quantify the cost of their compressed air operations. Open-ended discussion revealed that the two elements were not always associated with one another for achievable savings potential.

Suppliers believe they can identify and eliminate a large amount of waste in their customers' systems, and strongly compete with one another on efficiency in the traditional environment of compressor sales. The answers to the questions shown below illustrate the confidence that suppliers have in their ability to find waste and, by their high proportion of savings estimated in the distribution system, demonstrate at least a general understanding that maximum savings will come from a system-wide approach. They promise they can save their customers 24 to 27 percent on average. Suppliers have a high level of confidence that they can save their customers a great deal of money.

End-users demonstrate good basic understanding of their compressed air costs. They also demonstrate good general understanding of waste sources. They still do not put a high priority on eliminating waste. They certainly are not demanding associated products and services from the market at large. Basic understanding of costs and waste has not inspired action. But they are open to training. Training to change market behavior will need to be targeted to quantifying the savings potential and emphasizing the ease and cost-effectiveness of doing so with specific upgrade examples.

Are end-users aware of their compressed air costs?

| | |
|---|---|
| Percentage that can estimate utility bill cost. Q51. | 61% |
| Percentage willing to estimate compressed air portion of electric bill. Q52. | 81% |
| Percentage that can estimate both (and implicitly, estimate compressed air cost). | 56% |
| Percentage that regards compressed air as a very expensive part of their operation. Q53. | 60% |

Are suppliers and end-users aware of the system-wide sources of waste?

| | |
|---|---|
| Customer estimate of percent of waste outside compressor room. Q50. | 69% |
| Supplier estimate of savings potential from optimization services (controls + outside compressor room), divided by total savings potential. Q36/(Q34 + Q36) | 47% |

How much can be saved?

| | |
|---|---|
| Supplier estimate of percentage of customers that can cost-effectively invest in buying the high efficiency versions of compressors and dryers compared with standard efficiency versions of the same equipment when it is time for expansion/replacement. Q33. | 74% |
| How much typically can be saved through such capital improvements? Q34. | 24% |
| Suppliers' estimate of the percentage of New Jersey customers that can cost-effectively invest in buying optimization services that would help customers reconfigure their compressed air system for less energy use? Q35. | 69% |
| How much typically can be saved through such non-capital improvements? Q36. | 21% |
| Percentage savings offered by suppliers to customers with compressor horsepower less than 100 hp. Q42a. | 24% |
| Percentage savings offered by suppliers to customers with compressor horsepower greater than 100 hp. Q42b. | 27% |

***Progress Indicator 2: Interest in compressed air training***

As was illustrated in Indicator 3 above, the suppliers as a group needed to be better educated to handle the demand created by a PSE&G energy efficiency program. When asked how staff is currently trained, answers ranged from in-the-field training to formal classroom instruction. Half of the suppliers interviewed felt they could benefit from training; however only one (eight percent) was certain his company would pay for it. Of three suppliers who responded with what they considered be a reasonable cost, the following results were noted:

$195 for one day of training;
$300 per person; and
$500 per person.

Half of the interviewees were familiar with the Compressed Air Challenge (CAC) and attended the training sessions. Some of the attendees were trainers for the CAC. Some comments from the suppliers regarding the CAC training are listed below.

"Too many vendors involved."
"The vendors doing the training were in the interest of trying to sell their products."
"The training was too basic, even for many of the customers."

Customer training should include exercises that estimate the cost and savings potential for each customer's compressed air plant. Given that the resistance financial officers have to investing in compressed air efficiency is also a barrier, training should include calculations that express savings potential in financial terminology, not just payback time.

Has there been training in the area recently?

| | |
|---|---|
| Percentage of customers that have received formal training in the last two years. Q54. | 14%<br>(0% CAC) |
| Percentage of suppliers who are familiar or somewhat familiar with the Compressed Air Challenge Q60. | 58% |
| Percentage of suppliers that have attended a Compressed Air Challenge workshop in the past two years. Q61. | 58% |
| Percentage of suppliers that have received training in the classroom or seminars. Q59. | 33% |
| Percentage of suppliers that offer educational seminars. Q2. | 42% |

Is training appealing?

| | |
|---|---|
| Percentage of customers that would like training, depending on topic. Q58. | 100% |
| Percentage of suppliers whose sales staff would benefit from training on selling cost-cutting upgrade services. Q56. | 50% |
| Percentage of suppliers that would pay for sales staff training. Q58. | 8% Yes<br>42% No<br>25% Maybe |

***Progress Indicator 3: Supplier product development***

Metrics that gauge this progress indicator are included in end-effect indicator on supplier capability. Product availability was one of the features that sharply separated the suppliers from one another. When comparing vendors, the data show that the progressive vendors offered a complete line of services from metering to audits to leak detection and repair, whereas the traditional vendors offered none of that except when diagnosing compressor operation problems. The fact that air flow metering was included as part of the general suite of available services from firms offering system-wide diagnosis was surprising and promising. In other parts of the country flow metering is only occasionally found as a service offered because of the expense of accurate equipment and lack of appreciation for its importance in system analysis.

***Progress Indicator 4: Customer management support***

Lack of management support is an issue for some customers, the number one barrier for two of them, but generally does not appear to be an insurmountable problem. According to interviewed customers it is the only the seventh most common barrier to increasing priority of compressed air efficiency. Lack of available capital, an issue that can be a euphemism for a lack of management support, also is not a major problem for customers, though suppliers believe (or are told) otherwise.

The only serious management issue that appears as a barrier is that maximum payback times of two years or less are a simple reality in today's industrial environment. Often system improvements pay for themselves in months, but sometimes they take longer. No compressed air market transformation effort is going to change such a fundamental business issue.

***Progress Indicator 5: Supplier marketing of system-wide energy efficiency services***
In the short term at least, until end-users demand system-wide energy efficiency services in larger numbers, the burden of action lies upon aggressive suppliers. Unsolicited marketing is expensive, but is a sure way to increase market share for a new product or when in a competitive market. In the survey, customers reported moderately high activity by suppliers in this regard. Vendors led the activity. What they were selling varied widely, from leak detection and repair services to preventive maintenance, energy audits, and energy saving equipment such as compressors. The marketing was largely unsuccessful. Thirty percent of the customers acknowledged being approached, but only two percent of them have bought the promoted service so far. Five percent are still considering the proposition. This low success rate reinforces the need to target customers more than suppliers in program intervention. No matter how much suppliers want to sell a service, they will not be able to do so if potential customers are unwilling to buy.

Suppliers in this study and in previous studies consistently reported that they profit more from labor-oriented sales than equipment sales. The fact that 30 percent of suppliers in this survey pay higher commissions for labor-oriented services and that 44 percent take higher margin on labor-oriented services is concrete evidence of this contention. Ultimately, it should make suppliers receptive to the idea of promoting labor-intensive system-wide optimization services once customers start asking for them.

This indicator should continue to be measured as evidence of progress but should not be the primary target of intervention efforts.

Awareness of non-energy benefits from improving system operating efficiency among vendors was moderate at best. Perhaps the biggest real benefit of an optimized system, better pressure control, was only mentioned as a touted benefit three times. Another benefit, reducing air loads sufficiently to either avoid compressor purchase or increase compressor back-up capacity, was noted twice. Improved reliability and longevity were both cited more often, seven and four times, respectively, and reflect the traditional values of compressor sales more than that of improved system operation. Dry air, oil-free air and quieter operation also were mentioned. Non-energy benefits can be a crucial selling point, but those mentioned by suppliers generally do not reflect benefits directly derived from improved system efficiency projects.

Commitment to marketing system-wide energy efficiency

| | |
|---|---|
| Percentage of customers approached unsolicited about compressed air system services. Q63. | 30% |

Business practices that would encourage services-oriented marketing

| | |
|---|---|
| Percentage of suppliers that pay higher commissions for selling high efficiency equipment. Q47. | 30% |
| Percentage of suppliers that pay higher commissions for selling labor-oriented services compared to equipment sales. Q49. | 44% |

ESCo activity

| | |
|---|---|
| Percentage of customers that have been contacted by an ESCo regarding compressed air. Q62. | 7% |

# 3.0 Conclusions

PSE&G customers spend over $35 million dollars a year on compressed air. These customers have significant potential for energy savings by eliminating waste throughout their compressed air systems. The potential savings is not concentrated in any single industry; it is concentrated in larger customers across many industries. Twenty-one percent of PSE&G's biggest customers manage 68 percent of the total horsepower in the service territory.

Customers have a reasonably good understanding of their compressed air costs. They also have a good general sense of where in their compressed air systems they waste the most energy. However, they rank compressed air system management as a low priority. They have not been responsive to unsolicited proposals from suppliers to reduce their compressed air costs, but their interest has increased in the last two years. This lack of response may be in part because they are so predisposed use to their incumbent contractor. Customers perform a moderate level of operations and maintenance activity on their own to reduce their compressed air costs, but their efforts are not systematic and they acknowledge not knowing how much money they are throwing away. Customers would welcome training opportunities to gain some of that knowledge and perhaps to make them more informed buyers. Facilities engineers and their managers are interested in receiving proposals that are truthful and can help them recover their costs in less than one to three years.

Suppliers can be distinctly split into two groups: suppliers that understand the importance of system-wide compressed air system management, and suppliers that believe that compressed air service means solely keeping the compressed air plant running without placing a burden on the plant engineer. The progressive suppliers often must operate like their more traditional counterparts in order to be responsive to customer requests. These system-oriented firms tend to be larger and tend to conduct business both in New Jersey and out of state. During early market transformation efforts, these firms are likely to be far more receptive to outreach than traditional compressor-only-oriented firms. Whereas systems-oriented firms would welcome individualized utility support, other companies are likely to be non-responsive to even enthusiastic systems-oriented outreach.

Overall, the compressed air equipment and services market in New Jersey falls far short of capturing available savings, and without intervention by interested parties or gross changes in market factors (such as major electricity price increases), it will not change its pattern of behavior. Based on the scores made for the baseline study portion of this project, the market has only progressed 20 to 30 percent of the way from one that ignores energy waste beyond the compressor to one that aggressively eliminates it throughout the compressed air plant, air distribution system, and end-uses.

# 4.0 Recommendations

Although not in a state of infancy, New Jersey's compressed air market has yet to mature in its understanding and implementation of compressed air optimization services. Several individual market participants embrace system-wide efficiency services, but the majority of customers and suppliers do not realize the value of improving system efficiency beyond improving the compressor itself.

Because the market is not mature, many different program activities can positively influence market behavior. The recommendations below represent a large sampling of possible actions. PSE&G obviously does not have sufficient funding to implement all the recommendations. Due to the lack of basic understanding of compressed air efficiency, Aspen recommends two primary points of emphasis for program development: customer training, and individual support of the precocious vendors that do grasp the cost-effectiveness of system-wide optimization. These two recommendations are presented first. The additional recommendations will all help, but are of secondary importance at this time. They are presented in the order of the stages of market development illustrated in Figure 3:

## ***Primary Recommendation 1: Training***

Training educates customers about their savings potential. As discussed in the results, 42 percent of them cannot estimate their operating costs, and most seem unaware of the savings potential. Training will make customers more attractive to suppliers. Training content should include an exercise to calculate compressed air cost and savings potential for each attendee's facility and a sub-section on expressing upgrade value in terms familiar and persuasive to financial officers. Training should not dwell on the basics, however. Over half of end-users already can estimate their costs. They need concrete demonstration of techniques to cut their costs. Case studies, either local or national, would be valuable training components. See the topics list below for expressed interests.

Research from other parts of the country supports the focus on training. In Pacific Energy Associates' compressed air research in the Pacific Northwest, 13 of 21 suppliers interviewed recommended that customer education be pursued to increase the compressed air services market. No other intervention, including rebates, was recommended more than twice. PSE&G may not want to restrict training solely to the traditional facility engineer audience, nor to in-person seminars. Financial officers are an important audience to target to overcome management support barriers. Customers welcome alternative media. Consider technical topic videos; the U.S. Department of Energy or New England utility companies may be interested in cofunding their production because the issues are not specific to New Jersey. End-users often prefer a training format that requires less time than do workshops.

Marketing training is key to success. Although customers expressed strong interest in training during interviews, in reality they may be difficult to persuade when training is offered because of the time commitment required.

Nine customers expressed interest in training through videos, eight were interested in seminars, and nine were interested in one-on-one visits. In large volumes, videos are less expensive and less time consuming than seminars. Videos are also more likely to attract smaller manufacturers who cannot take the time to attend off-site seminars. Potential topics and formats to consider include the following:

- An entertaining 10- or 15-minute video on the cost of compressed air and the importance of eliminating leaks and only using compressed air where needed. The target audience would be plant floor staff already assembled for a periodic safety review or monthly status meeting. This idea is based on a specific customer request from the New England study.

- A series of 30-minute technical videos on specific topics of interest to maintenance staff and engineers. Potential topics for consideration include:

| *Training topic* | *Number of Customers Who Chose Topic* |
|---|---|
| Optimizing compressed air system operation | 23 |
| Air compressor controls | 20 |
| Finding and eliminating leaks | 19 |
| Basic operations and maintenance | 19 |
| Smart piping strategies[1] | 14 |
| Types of air compressors and energy efficiency | 12 |
| Air compressor analysis software | 6 |
| Ways to reduce water content in the compressed air | 1 |

Customers who had attended training seminars were more likely to be able to estimate their annual electricity and compressed air operating costs. Seventy-five percent of trainees could estimate both their monthly electric bill and the percentage of that bill that was used on compressed air. Fifty-seven percent of non-trainees could do the same. Customer seminars should not try to turn attendees into compressed air experts; instead, they should transform them into informed buyers of compressed air efficiency-related services. Case studies should be included in training and in distributed literature and should emphasize non-energy benefits such as smoother pressure supply and the avoided capital expense of buying new compressors.

Training should include techniques to earn upper management support for compressed air system upgrades. Five possible techniques are to: (1) require attendance of financial management personnel during project kick-off meetings to ensure support for subsequent activities, (2) emphasize the value of process quality improvements (e.g. due to steadier pressure supply) which can be far more valuable than avoided energy costs, (3) emphasize the avoided capital cost of buying additional compressors, (4) recast technical feasibility case studies as investment case studies for the financial officer audience, and (5) use savings from initial projects to fund later projects. ENERGY STAR® training emphasizes this last technique.

[1] Most topics are suitable for both smaller and larger customers. Based on the survey data, pressure management techniques should be particularly emphasized to smaller customers, as they operate their plants at higher pressures.

### ***Primary Recommendation 2: Individual support of suppliers that support system-wide efficiency upgrades***

There are only three or four compressed air equipment and service providers located in New Jersey and identified in this study that demonstrate a serious commitment to system-wide energy efficiency. We believe that the system-wide efficiency approach is the only approach that can capture all cost-effective savings possible for a particular customer. PSE&G program support should focus on helping capable and experienced vendors deliver system-wide efficiency services. Specific support that would be beneficial includes case studies with demonstration before-after power metering, training for customers led by these suppliers, and training of these suppliers by experts from other parts of the country. If possible to do without compromising utility objectivity, suppliers really would appreciate PSE&G directing customers interested in system-wide upgrades to them.

### ***Other Recommendations***

The above two recommendations are believed to be most important at this stage because they address the first two progress stages. Additional intervention can help as well. Possible actions follow, by progress and end-effect stages.

**Help customers recognize savings potential** – See primary recommendation 1, *Training*.

**Help suppliers recognize savings potential** – See primary recommendation 2, *Individual Support of Suppliers*.

**Support suppliers with product development – direct funding of optimization services.** The fastest way to encourage suppliers to develop comprehensive optimization service offerings is to develop an approved scope of work for such a project and then pay for all or part of it. Smaller customers may require standardized contracts for funding of compressed air services.[2] Smaller manufacturers are the most challenging targets for market transformation. To efficiently deliver consultative support to them, PSE&G and suppliers should develop a standardized audit scope and price structure that is endorsed by PSE&G. Customers would retain performance risk, but also know that the utility company is monitoring supplier performance quality. Long-term transformation is not certain.

**Support suppliers with product development – aggressively promote optimization at the time of prospective compressor replacement.** It is difficult to persuade a facilities engineer to start a project on a system that appears to be in working order. However, when replacement or additional compressors are being considered, the prospect of a less expensive alternative is most attractive. The possibility of avoiding a capital purchase of another compressor is a valuable non-energy benefit to eliminating system waste. Usually compressor replacements are not urgent because backup units are available, which makes this recommendation a possibility. The most aggressive approach to implement the recommendation would be to make compressor rebates contingent upon completion of a compressed air system study.

[2] This recommendation is taken from a white paper written for NEES: "Compressed Air Efficiency Services in Medium-Sized Manufacturers," by Peter J. Barrer, Demand Management Institute, undated.

**Enlist customer management support** – Eventually, PSE&G may want to team with EPA's ENERGY STAR and host training seminars for financial officers on the benefits of energy efficiency. This is not a primary recommendation.

**Help suppliers market, sell, and implement system-wide efficiency services -** Link interested customers with system-oriented suppliers. See primary recommendation 2, *Individual Support of Suppliers*.

**Help suppliers market, sell, and implement system-wide efficiency services - equipment incentives.** Rebates can successfully buy energy efficiency. Customers are overwhelmingly in favor of equipment incentives (Q71), not just for compressors but for demand expanders, receivers, and other auxiliary equipment. Suppliers that complete many incentive applications want incentives that can be standardized as much as possible. Published incentives or incentive algorithms specifically designed for improving part load performance could spur activity of relatively low-cost upgrades that save as much energy as does compressor replacement. Specific options to consider that would improve system part load efficiency are:

- Incentive funding for compressed air storage tanks (receivers). Receivers are inexpensive if customers have room to install them. The basis for rebate could be either standardized (e.g. $1 per gallon up to 5 gallons per installed compressor cfm) or performance based, requiring spot metering (e.g. $1 per gallon up to five-minute unloaded times at 50 percent flow and 10 psi pressure range). Numeric values are for illustrative purposes only.

- Standardized incentive pricing for demand expanders/flow controllers (XCEED™ by Honeywell, ConserveAIR™ by ConserveAIR, XpandAIR™ by Zeks). Incentives must be set carefully so that the levels reflect the incremental benefit of the controller and receiver over that of the receiver without a controller. They also must ensure that system-wide study is performed in advance of installation.

- Incentives for variable speed drive part load control of twin-rotor screw air compressors.

Anecdotal reporting indicates that when program administrative costs exceed 30 percent of the incentive, their worth declines substantially. Similarly, if incentives fall below a certain total magnitude, interest declines and the incentives lose their effectiveness as tools to change behavior. It becomes a free rider payment.

**Help suppliers market, sell, and implement system-wide efficiency services - support standardization of compressor efficiency ratings publication.** CAGI is succeeding in persuading manufacturers to test compressor performance according to standardized procedures. However, vendors are not conveying these data to customers for easy comparison between models. PSE&G should support CAGI's standardization efforts. Specifically, consider requiring submission of standardized performance data sheets by sponsors before paying incentives, and enlist vendors' support in updating marketing literature. Encourage CAGI to devise standardized part load performance tests as well as full load tests, just as SEER and HSPF ratings are available for air conditioners and heat pumps.

**Help suppliers market, sell, and implement system-wide efficiency services - screening worksheet.** Suppliers would welcome utility development of a two- or three-page screening worksheet. Distributed either during customer training seminars or given to suppliers to distribute, the worksheet would collect key customer data to help suppliers identify customers that are good candidates for optimization services.

Similarly, a concise guide to identifying when compressed air systems are operating sub-optimally and worthy of intensive study by a specialist would be an effective tool to distribute to general industrial energy auditors. Utility companies and their contractors excel at creating this type of packaged product. Examples of the types of practical in-field diagnostic techniques that would be worthy of consideration include:

- Measuring the compressor load-unload cycle time (is it at least two minutes?).
- Listening for leaks at lunchtime when the plant is quieter.
- Measuring compressor power at lunchtime and at peak production time and comparing the difference.
- Providing a list of key interview questions to ask (history of problems, hours of operation and of maintenance per week, review of air distribution system layout).

A short guide, less than ten pages with worksheets and perhaps accompanied by a short training video or in-person seminar, would open up diagnosis of compressed air optimization opportunities to a larger audience that that currently being served by traditional vendors.

**Help customers implement internal system-wide efficiency activities - free loan of ultrasonic leak detector.** Most of the respondents are aware that leak detection and repair are a big source of energy savings. Clearly, education that persuades customers to conduct routine inspection and repair is the best solution, but there are barriers to overcome. With 24-hour per day, 7-day per week operations it is difficult identifying leaks simply by walking through the plant and listening with the naked ear. Ultrasonic leak detectors eliminate this barrier, but at a cost of $2,000 to $5,000, many customers regard them as too expensive for occasional use. No-cost leasing of ultrasonic leak detectors would be a low capital cost program compared with other incentive programs. Customers should be given a deadline to return the equipment, which may help move this non-critical preventive action higher up on staff priority lists.

Customer-conducted leak detection considerably increases the likelihood of follow-up repairs. It is not uncommon for experts to survey a facility, identify leaks, leave, and then return six months later to find the leaks still wasting air. When customers identify the leaks themselves they have a sense of ownership about the problem and are more likely to take follow-up action –clearly a benefit to promoting leak detection directly by the customer. Sixty-four percent of the customers interviewed said that the free loan of leak detection equipment would be attractive to them.

Although the setup cost of an ultrasonic leak detection program is low, success will depend on investing aggressively in targeted marketing and must be accompanied by training in the importance of routine leak reduction. An accompanying video for training might accomplish both goals. As an additional benefit, the marketing literature could mention that ultrasonic detectors could be used for purposes other than compressed air leak detection. Based on customer responses, direct mail is the best way to reach facilities engineers. If PSE&G maintains a technical contact database (such as the one generated for this project's interview recruitment), then direct mailing would be most effective. Marketing through utility account representatives would be second best. Bill inserts will not work because facilities engineers do not receive them, and advertising in trade journal will not work because customers did not cite any local trade journals that they generally read.

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# Appendix A: Methodology

The following is a summary of the market assessment tasks performed for this project.

**Define metrics.** Research staff created market transformation metrics to track compressed air market behavior over time. The metrics indicate transformation from a market that offers basic products and services to one that naturally promotes high efficiency products and services. The metrics have been applied for the first time in this project during the baselining exercise. In later years, the same questions can be asked again and the answers can be compared to 1999-2000 results for trend analysis.

**Review literature.** Staff reviewed the documents listed in the Bibliography in preparation for questionnaire development and to assist in calculating energy savings potential and other metrics.

**Design questionnaires.** Research staff created questionnaires for suppliers and customers. The design included predominantly closed-ended questions structured with repeatability in mind, so that they can be asked again in the future and the answers can be used as metrics to help measure market transformation. The questionnaires also include open-ended questions to provide opportunities for general discussion and to give "texture" to the interviews.

**Design sampling plan.** The work plan included a data collection and sampling plan for 12 supplier interviews and 25 customer interviews. Customer interview selection was based on selection from a size-stratified random sample. Size was defined by total non-backup compressed air plant size. The size categories are shown in Table A-1.

## Table A-1: Customer Categories

| *Size* | *Total Non-backup Compressor Horsepower* |
|---|---|
| Sub-Small | Under 100 hp |
| Small | 100 to 500 hp |
| Large | Over 500 hp |

Because the population data contain no direct indicators of compressor plant size, general engineering-based conversion factors were applied to predict compressor horsepower from available plant peak demand data. To avoid bias, the sample included customers with expected plant size under 100 hp. Ultimately, the conversion factor correctly stratified 64 percent of the customers and sufficiently indicated that interviewers were able to interview the desired number of customers in each stratum.

**Supplier interviews.** End-users buy a wide range of products and services to keep their compressed air plants running. Companies that sell these products and services were grouped under the general term "suppliers." Suppliers fall into many different, overlapping sub-categories. The logical structure used for this project places them in the five categories shown in Table A-2.

## Table A-2: Supplier Categories

| *Category (Number of interviewees)* | *Product* |
|---|---|
| Equipment vendors (9) | Air compressors, dryers, and distribution system equipment such as traps, nozzles, receivers, and gauges. May offer fee-based consulting. Specialize in compressed air; generally react to client needs. |
| Energy service companies (0) | Proactive providers of energy-related upgrade projects. Typically use energy savings to pay for projects. Typically act as general contractors. Historically have promoted energy upgrades other than compressed air. |
| Expert consultants (1) | Advice and compressed air system audits. May act as general contractors to implement their recommendations. Specialists in compressed air. Do not sell equipment. |
| Service provider/O & M Contractor (1) | Contracted services. Do not sell major compressed air equipment such as compressors. May sell control equipment. |
| General engineering firms (0) | Industrial system design, advice, and project management, typically to larger firms. Recommend/manage compressed air projects, among many others. Potential compressed air ally. |
| Manufacturer (2) | Build compressors and related equipment and sell them to vendors. May have direct sales team for national accounts. |

Although not a statistical sample, the number of suppliers interviewed of each type generally reflected the proportion of suppliers found in the region based on utility staff referrals and Yellow Pages review. Staff interviewed representatives from two firms that specifically sell air demand management devices because this service market was not well understood before the study. Vendors that sell demand expanders are a hybrid between traditional vendors and consultants. They sell hardware but must perform advanced system-wide analysis to estimate savings and configure their device properly. Although there is question about whether or not demand expanders themselves contribute substantial energy savings, there is little doubt that the combination of expander installation plus associated actions typically inspired by the demand expander assessment (installing receivers, reducing distribution system pressure, system-wide analysis) often eliminates substantial waste. Staff also met with a compressor rebuilder to gather his unique perspective on market developments and determine the prospects and ramifications market transformation in that arena. Finally, an interviewer met with two manufacturers, one of whom sells equipment directly to customers.

ESCos were not targeted for interviews because preliminary investigation suggested that their level of activity in compressed air projects in New Jersey was minimal. Analysts relied on previous research to define their roles. Industrial general engineering firm may play a more prominent role in compressed air in New Jersey than ESCos, however their significance was judged to be less than that of other types of suppliers. Given the budgetary constraint of 12 supplier interviews, they were excluded as well.

Interviewees are listed in Table A-3 in the order interviewed. Table A-1 illustrates the distribution by type. Thirteen supplier representatives from 12 companies were interviewed. Eleven of the representatives were interviewed in person. Eleven questionnaires were completed for tabulation.[3] Researchers believe the list is a accurately represents firms working with compressed air in the region.[4]

**Table A-3: Supplier Interviewees**

| *Interviewee* | *Supplier* | *Location* | *Supplier Type* |
|---|---|---|---|
| John Scornavacca | Spohror | Cedar Grove, NJ | Vendor |
| Frank Peterson | American Air Compr. | North Bergen NJ | Service Provider |
| Ed Schlatter | Airmatic Compressor | South Hackensack, NJ | Vendor |
| William Vowteras | Airmatic Compressor | South Hackensack, NJ | Vendor |
| Mark Pfeifer | Sullair Corporation | Langhorne, PA | Manufacturer |
| Steve Piper | Ingersoll-Rand | Edison, NJ | Manufacturer & Vendor |
| Charles Tar | Industrial Air Compr., Inc. | South Amboy, NJ | Vendor |
| Ethan Vielehr | Air & Gas Technologies | Cliffwood Beach, NJ | Vendor |
| Niff Ambrosino | Scales Air Compressor | West Patterson, NJ | Vendor |
| Robert Mirel | RJ Mirel Associates | Chestertown, NY | Consultant |
| Jim Kenney, Jr. | Metropolitan Air Comp. | Passaic, NJ | Vendor |
| Bill Bullock | APT Honeywell | Laurel, MD | Vendor |
| Tom | Action Air Compressor | Princeton, NJ | Vendor |

Suppliers were interviewed about their perspectives on compressed air systems as small as 1 hp.

**Customer interviews.** The survey design goal was to interview company representatives of 17 small and eight large companies and to collect plant size data on nine sub-small customers. Staff completed 16 small and nine large customer interviews, and gathered size data on nine other companies.

A random sample of 87 customers was drawn from the PSE&G operating area with the goal of completing 25 interviews. Each customer received an introductory letter from the utility before receiving calls. Interviews were conducted over a one-month period. Fifty-three companies were called, 25 interviews were conducted, nine companies had sub-small compressor plants, 17

[3]One of the suppliers, Action Air Compressor Corporation, was not willing to complete the survey. A partial interview was conducted over the course of three separate phone calls. The complete interview with Metropolitan Air Compressors was conducted via phone. A single questionnaire based on interviews with two representatives was completed for Airmatic.

[4] According to *Improving Compressed Air System Performance: A Sourcebook for Industry*, p. C-3, 500 to 600 air compressor distributors sell 85 to 90 percent of all compressors nationwide. Based on data shown in Table 4, less than one percent of industrial end-users are in the PSE&G service territory. Presuming that vendors are distributed in proportion to customers, interviews with six vendors would have been sufficient. Vendors from twelve companies were interviewed.

contact persons did not return calls, and one contact person refused the interview. The customer rejection rate (those that declined participation), was only four percent. Fifteen percent of the contacts had plants smaller than 100 hp. Customers that did not decline to participate and did not complete interviews constituted 32 percent of the sample.

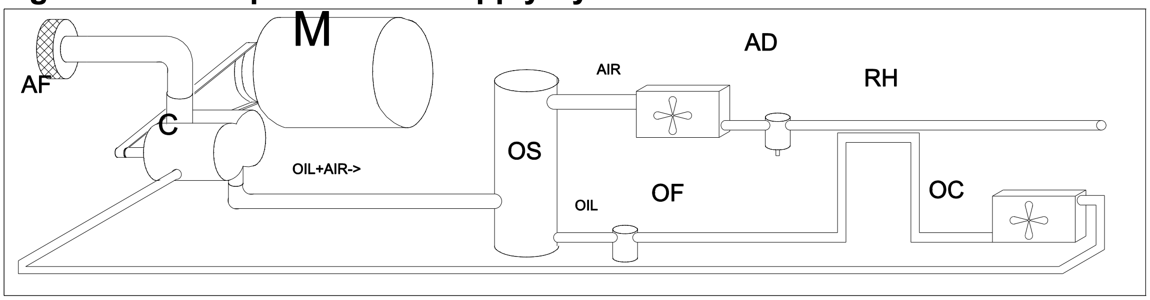
### Table A-4: Customer Interview Results

| | | |
|---|---|---|
| Completed Interviews | | 25 |
| Attempted, uncompleted interviews | | |
| Didn't return calls | 17 | |
| Too small (goal was 9) | 9 | |
| Refused | 1 | |
| Other | 1 | |
| Subtotal | | 28 |
| Customers Not Called | | 34 |
| Total | | 87 |

# Appendix B: Compressed Air System Components

Appendix B describes the components of a complete compressed air system. Figure B-1 shows a basic compressed air supply system upstream of the receiver and distribution system.

### Figure B-1: Compressed Air Supply System[5]




| | |
|---|---|
| AD | air dryer |
| AF | air filter |
| C | compressor (twin screw illustrated) |
| M | motor |
| OC | oil cooler |
| OF | oil filter |
| OS | oil separator |
| RH | reheat exchanger (optional) |

Air flows from left to right in Figure B-1. A screw compressor[6] draws ambient air through the air filter. In northern climates such as New Jersey incoming air should be obtained from outside the building instead of inside because it is cooler. Cool air is denser than warm air and requires less mechanical compression. The motor turns one lobe of the compressor via belt drive and draws in little discrete portions of air. At the same time, suction or a small oil pump (not shown) injects oil or transmission fluid into the air stream to lubricate the lobes and to act as a coolant. The turning lobes compress the air-oil mixture and eject it out to the oil separator. This happens up to 400 times per second with screw compressors. In the separator, gravity and perforated baffles separate the oil and air as the compressor pushes the air through it. The clean air travels through a dryer (air-cooled radiator and condensate trap are shown) to remove condensing moisture and continues to the receiver or main air line. The oil removed from the air in the separator goes through a filter for cleaning. In the diagram the hot oil reheats the air to recover about 15 percent of oil's heat energy into the air stream before going to the oil cooler to reject it. Rejected heat

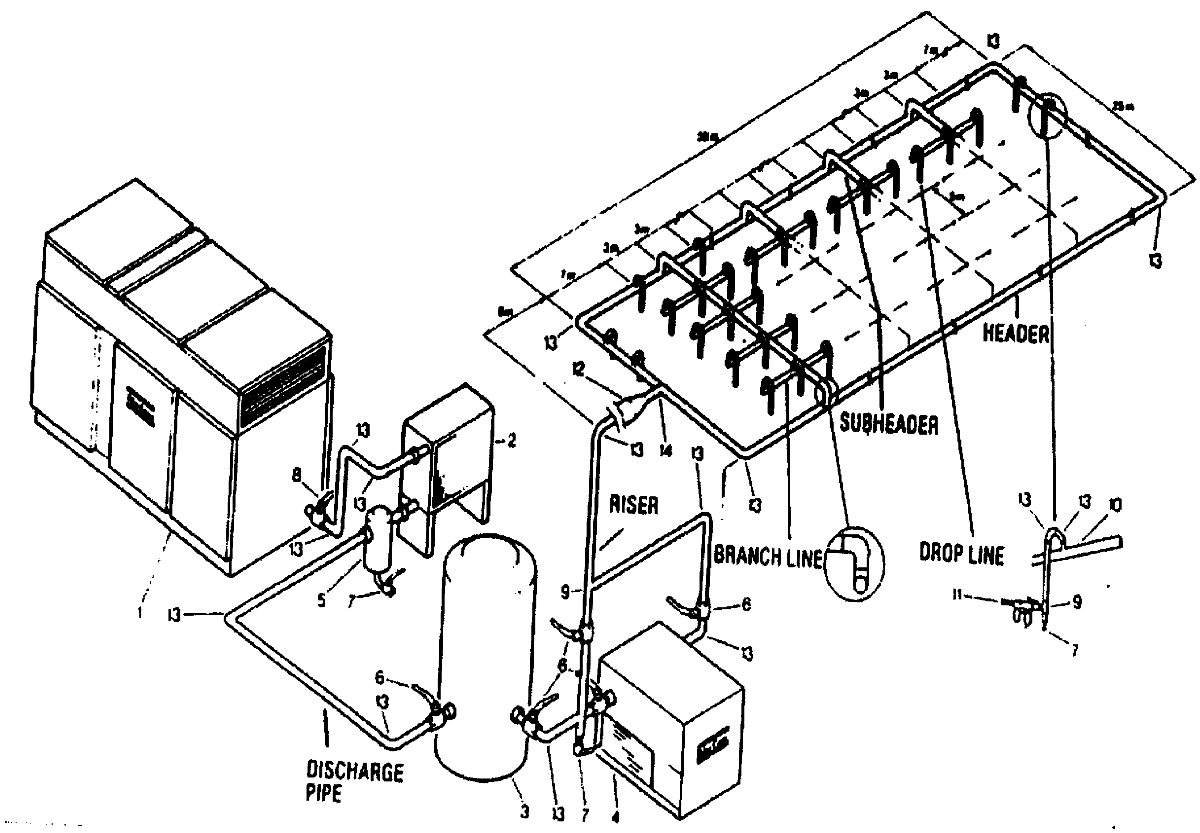
[5] From *A Guidebook for Screw Air Compressor Controls: Operating Principles and Selection for Minimum Energy Use*, for Bonneville Power Administration by Jonathan B. Maxwell, November 1992, p. 9.

[6] "Rotary compressors have gained popularity and are now the 'workhorse' of American industry. They are most commonly used in sizes from about 30-200 hp. The most common type of rotary compressor is the helical twin screw-type (also known as rotary screw or helical lobe)….Rotary screw compressors have low initial cost, compact size, low weight, and are easy to maintain (compared to reciprocating units)." From *Improving Compressed Air System Performance: A Sourcebook for Industry*, for the US Department of Energy by Lawrence Berkeley National Laboratory and Resource Dynamics Corporation, April 1998, pp. 1-4. The smallest compressors still are single-acting reciprocating units, and the largest compressors are centrifugal with an occasional double-acting reciprocating units.

from the air dryer also can be recovered (not shown). In the Northeast this heat can alternately be recovered to warm the air space.

Figure B-2 traces the flow of air through distribution system components after it leaves the dryer or reheater. Next, the clean, dry compressed air flows to the main receiver (item 4). A refrigerated dryer is shown after the receiver in Figure B-2. The air then flows up through a riser to the main header. In many systems, the best design is for the main header to be a continuous loop, with subheaders running off the main header and branches running off the subheaders. With this design, air always has at least two paths to reach the subheader demanding it. This design can reduce pressure-drop problems. Individual end-uses tap the compressed air via drop lines off the branches. Typically there will be a condensate trap and pressure regulator (item 11) with disconnect between the air supply line and the air-using equipment.

**Figure B-2: Compressed Air Distribution System**[7]




[7]*Northeast Utilities Compressed Air Seminar*, Atlas Copco, undated, unpaginated.

# Appendix C: Data Summary

C.1 Supplier On-Site Questionnaire
C.2 Customer Telephone Questionnaire
C.3 Tabulated Supplier Survey Results
C.4 Tabulated Customer Survey Results

# Appendix C.1

# Supplier On-Site Questionnaire

# Appendix C.2

# Customer Telephone Questionnaire

# Appendix C.3

# Tabulated Supplier Survey Results

# Appendix C.4

# Tabulated Customer Survey Results