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Small Compressed Air Market Assessment

Study of the energy efficiency of compressed air systems ≤100 hp

Prepared for Energy Trust of Oregon, Phil Degens & the Northwest Compressed Air Task Forces July 25, 2008

Contents

Executive Summary 3
Introduction 5
Study Goals 5
Background on Small Industrial Compressed Air Systems 5
Methodology 6
Market Summary....7
Size of the Northwest Compressor Market 7
Type of Compressors 7
Compressed Air Energy Usage in Northwest 8
Market Trends 8
Market Chain & Market Actors 9
Manufacturers & Vendors in the Northwest 9
Compressed Air Energy Consumption 12
Energy Efficiency Options 13
Program Recommendations 15
Present compressed air costs to end users when offering a program. 15
Advocate Leak Prevention Programs 15
Install variable speed drives and/or additional receiver storage 16
Potential Program Barriers 16
Estimated Potential Program Benefits 18
Next Steps 19
Conclusions 20
References 21
Appendices 22
Appendix A: Interview Findings 23
General 23
Manufacturers 23
Distributors/vendors 23
Users 23
Utility Program Managers 24
Interview Findings-Manufacturers 24
Interview findings – Distributors/Vendors 27
Interview findings – Consultants 27
Interview findings – End Users 29
Interview Findings – Utility Program Managers 29
Appendix B: Literature Review Results 32
Utility Program Descriptions 32
Appendix C: Interview Guides 35
Equipment Manufacturer Interview Guide 35
Utility Program Manager Interview Guide 41
End User Interview Guide 42
Consulting Engineer Interview Guide Questions 45

Executive Summary

This market assessment, commissioned by the Energy Trust of Oregon in partnership with Bonneville Power Administration, PacifiCorp and Idaho Power Company, is intended to characterize the market for small industrial compressed air systems in the Pacific Northwest states of Idaho, Washington, Montana, and Oregon. This report explores the market and savings potential of a large, but often overlooked segment of industrial compressed air systems. Based upon a review of the available literature and extensive interviews with market actors, The Cadmus Group finds that:

- Based on manufacturer surveys, there are approximately 15,000-17,000 compressors with nameplate ratings of less than 100 hp currently operating in the study area. Of those compressors, about 1,700 are between 50 and 100 hp; indicating that approximately 90% of compressors less than 100 hp are smaller than 50 hp.

- Energy consumption of compressors varies greatly depending upon operational schedule, load, and rated horse power. The United States Industrial Electric Motor Systems Market Opportunities Assessment indicates that run time for compressors in the 50 to 100 hp range is roughly 5,300 hours per year, or about 60% of full time.[2] At this rate, these systems might consume 198,000-396,000 kWh per year. (This corresponds to annual electricity bills of $19,800-$39,600 at $0.10/ kWh)

- The most cost effective efficiency measure for compressed air systems 100 hp and less is leak detection/repair. Other possible efficiency measures may include increasing storage capacity and installing VFDs on new systems. Energy savings through these measures are expected to range from 20-30% of total compressed air system usage.

- When end users of small compressed air systems were surveyed, 60% indicated they were somewhat likely or very likely to participate in energy efficiency programs for compressed air. Despite the potentially high level of interest, end users seemed to believe there were relatively low available savings, which were not deemed commensurate with the time and resources required to participate. It may be best to couple the marketing of the program with an understanding of estimated costs of compressed air by horsepower and run time. Perhaps if the consumer understood the cost of the compressed air system, the reaction might be different.

The data collected and presented in this report demonstrates that a potential program to support energy efficiency in small industrial compressed air systems (≤100 hp) should consider several factors when considering program design:

- **Targeted system size.** The best opportunity for energy savings in smaller industrial compressed air systems is in systems of 50 to 100 hp. Energy efficiency measures applied to systems smaller than 50 hp offer low cost effectiveness and are predicted to have low program participation.

- **Perceived and actual cost effectiveness for end user**. Energy and cost savings will depend primarily upon operational time. However the costs that the customer will incur will include: potential loss of production time, the time required to quantify energy savings (if a pre and post study is done), and administrative time.

- **The current state of end user awareness.** End users cited low perceived savings as a primary reason for not participating in a potential efficiency program for small compressed air systems. In order to sustain a successful program, end users may need to be educated, through outreach and targeted program marketing, about the operating costs of compressed air systems. Energy use, estimated by horsepower and run-time, could be converted into simple marketing materials and/or online calculators to convince end users of the need for improved energy efficiency.

Table 1: Preliminary Program Recommendations

Program Goal/Priority	**Proposed Approach**	**Rationale**
Improve energy efficiency with minimal cost	Ultrasonic leak detector loan program	Leak detection offers a benefit for all sized systems. Customers that are unwilling to invest in the proper equipment and/ or a consultant to conduct a full audit may be interested in borrowing the proper equipment when they understand the potential savings.
Encourage kWh savings	Prescriptive efficiency program with rebates	The cost savings from increased efficiency for small systems do not justify the expense of detailed analyses/audits from a custom program but financial incentives to support efficient components in new and/or retrofit systems may be more feasible.

Introduction

Industrial compressed air systems have been extensively studied nationwide and at the regional level. A number of utilities nationwide have implemented energy efficiency programs for compressed air systems with mixed success. It is generally agreed that energy efficiency measures for large compressed air systems (greater than 100 hp) offer cost effective and attractive energy and cost savings. Thus consultants have focused primarily on large systems, and they have been the primary target for utility energy efficiency programs. Smaller compressed air systems, 100 hp and less, have been generally ignored by consultants due to the low savings, compared with the high costs of system monitoring.

Study Goals

The study was developed with several key goals in mind, as identified by the Energy Trust and other key stakeholders:

- Characterize the market for small industrial compressed air systems in the Northwest
- Develop a first order estimate for energy efficiency savings for small compressed air systems, in particular for systems less than 100 horsepower
- Provide recommendations for one or more cost effective program approaches to deliver energy savings from this market
- Discuss the success and lessons learned from other compressed air energy efficiency programs

Background on Small Industrial Compressed Air Systems

Compressed air systems appear in a wide variety of industries: primary and secondary wood products, metals, electronics manufacturing, and transportation are a few significant examples in the Northwest region. While compressed air systems come in a wide variety of sizes and configurations, the focus of this report is on small industrial compressed air systems that have generally been omitted from other energy efficiency studies. Interviews with consultants and manufacturers in the compressed air industry suggested 50 horsepower as the threshold for small compressed air systems. Consultants have found that they cannot offer cost effective studies of systems smaller than 50 hp in the same way they would for larger systems, which offer greater potential energy savings. Both end users and consultants indicated that they are more likely to focus their time and resources on energy efficiency of systems 50 hp and above, rather than on smaller systems. The projected savings for systems less than 50 hp appears to be too small to justify significant utility incentive levels. Nevertheless, a considerable amount of energy savings is possible for systems in the 50-100 hp range. The remainder of this report will focus primarily on measures applicable to systems from 50-100 hp.

Methodology

This study of small compressed air systems includes targeted interviews of manufacturers, distributors, utility program managers, consultants, and end users of small compressed air. The selection of end users represents a regional cross section of industries most likely to have and use small compressed air systems. In addition, we have extracted the salient points of previous studies as they pertain to small compressed air systems, particularly those systems in the Northwest region that includes Oregon, Idaho, Washington and Montana. A breakdown of interviews conducted by market actor category is given in Table 2, below. A breakdown of end users interviewed, by industry, is given in Table 3. A list of key sources consulted in the literature review portion of this study is given in the References section at the end of this report. The survey instruments used to conduct market actor interviews are given in Appendix C.

This work focuses on *industrial* compressed air systems and does not consider air compressors used for commercial buildings, pneumatic controls or in retail service.

Table 2: Distribution of Market Actor Interviews

Market Actor Group	Number of Interviews (38)	Market Role
Manufacturer	5	Makes air compressors and related equipment.
Distributors and vendors	6	Sell air compressors on behalf of manufacturers to building and process operators.
Consulting Engineers	7	Provide a variety of design, specification, and efficiency services for compressed air systems.
Utilities	5	Funds and promotes energy efficiency programs including compressed air programs.
Building and Process Operators	15	Purchases, operates, maintains and uses compressed air systems.

Table 3: End User Interviews by Industry Category

SIC Industry Group	**Interviews**
20 Food and Kindred Products	**1**
23 Apparel and other Textile Products	**3**
36 Electronic and other Electric Equipment	**3**
26 Paper and Allied Products	**1**
34 Fabricated Metal Products	**7**

Market Summary

Size of the Northwest Compressor Market

Based on interview findings and prior research, there are an estimated 15,000-17,000 compressors in operation in Washington, Oregon, Idaho and Montana with a nameplate rating of 100 hp or below; and about 1,700 of those compressors are between 50 and 100 hp. There are about 1,000 new compressors of all horsepower sold each year in the Northwest region. This is comparable to a Wisconsin survey, which showed sales of about the same amount for approximately the same amount of manufacturing jobs in the region. Seventy-five to eighty-five percent of these 1,000 compressors sold are 100 hp and below. For comparison, an Easton survey in the Northeast indicated that 78% of the 1,500 PSE&G customers interviewed had compressed air systems less than 100 hp, totaling 50,000 hp for those systems.[1] Vendors we surveyed in the Northwest indicated that about 15-25% of total unit sales are for compressors in the 50-100 hp range. The Wisconsin compressor sales suggested that this number was as high as 25% of total sales in that region.[2]

Table 4 shows an estimate of compressor sold in the four states in the Northwest by horsepower size.

Table 4: Annual Compressor Unit Sales in the Northwest

Hp	Percent of total Sales*	Calculated unit sales per year
<50	60%	600
50-100	25%	250
>100	15%	150

** Based on vendor surveys and the Quantum and Easton reports*

Type of Compressors

The market for small compressors is divided, primarily, among rotary screw and reciprocating compressors. Centrifugal units are reserved for much larger applications. Vendors estimated that about 70% of the units sold (less than 100 hp) are rotary screw. The remainder of small compressors is reciprocating compressors, primarily used for very small horsepower (less than 10 hp) applications. A survey from the US Census Bureau shows that for single action reciprocating compressors sold in 1993, less than 1 % of those were over 25 hp.[3] Several studies confirm that most systems are likely to have two or more compressors. Our survey of vendors indicates that about half of all systems have multiple compressors. Of the end users with systems smaller than 100 hp surveyed for this report, 43% had more than one compressor. In some cases the additional compressor is used as a backup rather than a multiple compressor system. Vendors stated that 20-50% of total compressor sales are for replacement units, rather than for new systems.

[1] Easton Consultants & Xenergy. Opportunities for Industrial Motor Systems in the Pacific Northwest. 1999.
[2] Quantum Consulting. State of Wisconsin Department of Administration Division of Energy Business Programs: *Market Assessment Commercial and Industrial Equipment Supply Chains: Industrial boilers, compressed air systems, and pump systems*.
[3] MA35P -- PUMPS AND COMPRESSORS, US Census Bureau

Compressed Air Energy Usage in Northwest

A previous study of motor systems in the Northwest estimated energy due to motor systems at 4,618 aMW.[4] The Aspen survey of PSE&G customers showed that about one third of the total horsepower of systems in operation can be attributed to systems less than 100 hp. They concluded that the average horsepower for systems less than 100 hp was 68. Based on a weighted average of compressors less than 100 horsepower, we estimate that the average horsepower of these small systems in the Northwest is closer to 40 hp.

Table 5: Easton Survey Results Customers in PSE&G Territory (1,500 customers)[5]

Hp	Units in operation	Average hp	Total hp
<100	1182 (78.4%)	68	50,000
100-500	275 (18.2%)	200	53,000
>500	51 (3.4%)	1,100	54,000

Market Trends

The US Census Bureau survey of pump and compressor manufacturers indicates the largest changes in the industry are with very small and very large compressors. From 1994 to 2006, unit sales of single action reciprocating compressors between 1 ½ and 5 hp went up by over 200%.[3] Sales of rotary screw compressors (with discharge greater than 51 cfm) rose 127% for units below 40 hp and 115% for units greater than 300 hp. By contrast, unit sales for rotary screw compressors between 151 and 300 hp increased by only 1%; and unit sales for 41-150 hp units decreased by almost 7%. This data would suggest that as older systems are replaced, end users are redesigning systems to use multiple small compressors in place of one larger unit. The very large compressors are still in use for large manufacturing operations.

[4] Easton Consultants & Xenergy. Opportunities for Industrial Motor Systems in the Pacific Northwest. 1999. One megawatt of capacity produced continuously over a period of one year. 1 aMW = 1 MW x 8760 hours/year = 8,760 MWh = 8,760,000 kWh.

[5] Aspen Systems Corporation. *Compressed Air Systems Market Assessment in the Public Service Electric and Gas Service Territory*.

Market Chain & Market Actors

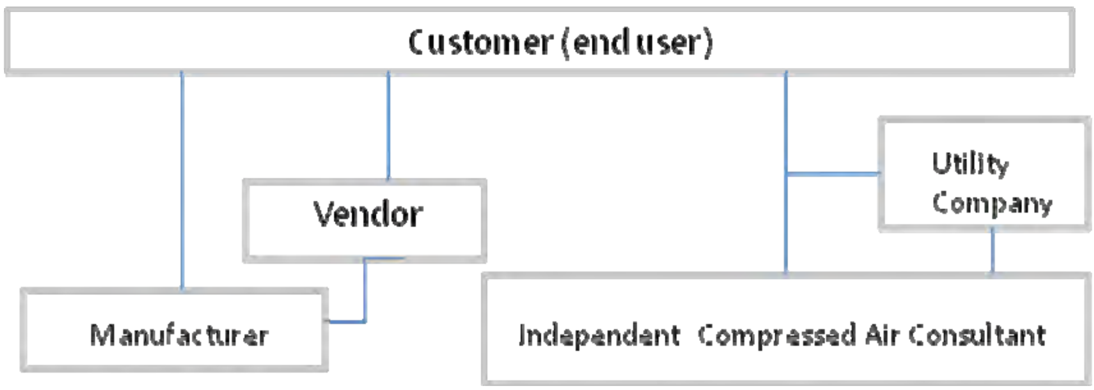

Figure 1: Compressed Air Market Flow[6]

Manufacturers & Vendors in the Northwest

The overwhelming leader in the Northwest industrial compressed air sales is Rogers Machinery, with an estimated 60% of the market share. Along with Atlas Copco and Sullair products, the sales of these three players represent the vast majority of the small compressed air market. Other manufacturers playing a lesser role include Ingersoll–Rand, Gardner Denver and Quincy. Many of the manufacturers, such as Ingersoll-Rand and Atlas Copco sell product directly to the end user. Gardner-Denver is sold primarily through Beckwith & Kuffel; Sullair through Dickinson Equipment; and Ingersoll-Rand through Portland Compressor: all major distributors in the Northwest.

Furthermore, some of the vendors have a larger presence in some states than others:

Table 7: Primary Vendors by State

Washington	Cascade Machinery; Beckwith & Kuffel; Dickinson
Oregon	Rogers Machinery; Cascade Machinery; Beckwith & Kuffel
Idaho	Compressor Pump & Service; Cascade Machinery
Montana	Energy Equipment & Supply, Inc

[6] U.S. Department of Energy 1998b. *Improving Compressed Air System Performance: A Sourcebook for Industry.*

Each of the major vendors sells product in the four states, however we estimate that almost half of all compressors are sold and operate in Washington. The following chart shows a relative comparison of compressors in each of the four states. This information is based on the Bureau of Labor and Statistic State Occupational Employment and Wage Estimates.[6] The Xenergy report findings are similar for the motor systems energy usage by state: WA: 44%; OR: 27%; ID: 19%; and MT: 10%.

Table 6: Estimated Compressors in Operation by State

State	Percentage of total Manufacturing in the region	Number of compressors (50-100 hp) in operation
Washington	46%	799
Oregon	37%	642
Idaho	12%	208
Montana	5%	87
Total		1,736

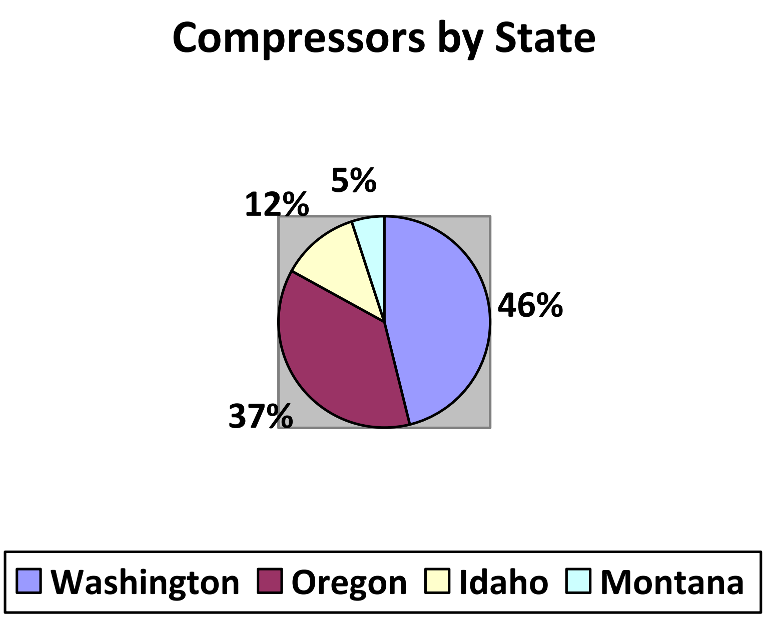

Figure 2: Compressors by State

Compressed Air Energy Consumption

Overall, compressed air may account for as much as 10% of all electricity and 16% of all motor system energy use in U.S. manufacturing industries.[7] Smaller air compressors, although they comprise an overwhelming majority of unit sales, account for only a small amount of electrical consumption. For example, a 5 hp reciprocating compressor may run for one shift only (about 2,000 hours per year) and consume less than 7,500 kWh annually. At $0.10 per kilowatt hour, this is roughly $750 of electricity per year. By contrast, a 50 hp compressor that operates longer, perhaps two shifts per week, would consume almost 150,000 kWh per year; at a cost of $15,000 per year. As system size increases, usage also tends to increase because the compressed air system becomes an increasingly significant investment and only applications heavily reliant on compressed air are likely to utilize larger systems. Table 8 below shows calculated energy usage and cost based on the operational time given in the DOE Motor Assessment report.[8] Each horsepower segment represents an average for several different industries.

Table 8: Estimated End User Annual Energy

hp	Average annual operation hours	Annual kWh usage (1 hp = 0.746 kW)	Average electricity cost at $0.10/ kWh
1-5	2,880	2150 - 10,742	$215 - $1074
6-20	3,050	13,650 – 45,500	$1,365 - $4,550
21-50	3,680	57,650 - 137,264	$5,765 - $13,726
51-100	5,329	202,747 – 397,543	$20,274 - $39,754

[7] U.S. Department of Energy 1998b. *Improving Compressed Air System Performance: A Sourcebook for Industry*
[8] U.S. Department of Energy 2003c. *United States Industrial Electric Motor Systems Market Opportunities Assessment.*

Energy Efficiency Options

Leak Detection. Leaks are present in all compressed air systems. The Compressed Air Challenge along with the Department of Energy state that leaks sometimes reduce a compressor's output by 20-30%.[9] Total energy savings depend upon the horsepower, pressure and operational time, and the current status of the system, but in general, savings of 10% or more can be available.[9] Typically leak repair is performed on an as needed emergency basis, when the end user can hear the leak or it compromises system function. This may lead to weeks or months of leaky system operation and lost energy. An ultrasonic leak detector can be used to reliably detect small and medium sized leaks that can't be heard, as well as large leaks. A leak detection and repair program could be incorporated into regular maintenance schedules for systems of all horsepower sizes. The cost of a leak detection unit ranges from $500 to $1500.

Variable Speed Drive (VSD) or Adjustable speed drive (ASD). Variable Speed Drive compressors have become increasingly popular in recent years. One article from Plant Services Magazine (May 2008) quotes a representative from Sullair as saying that the variable speed drive is now on "one out of every four compressors sold."[10] In contrast to their prevalence now, older reports, including The Electric Motor Assessment report from2002 shows that only 3% of rotary screw compressors had ASDs.[2] The estimates for energy savings vary considerably. The Motor Assessment report suggests a savings of 10% for installing ASDs on rotary screw compressors with variable loads. Other studies have reported savings estimates as high as 20-30%. The VSD is most effective for loads that vary over time by 30% of full load; the higher the horsepower, the more cost effective. Additionally this option will be more cost effective for systems running 2,000 or more hours per year. The increased number of variable speed drive compressors is likely due to the heightened awareness of energy efficiency in recent years. Additionally, with the advent of the Compressed Air Challenge and other educational resources, more vendors are being trained on these potentially energy saving options, which they can in turn offer to their customer base. Manufacturers are contributing to the widespread popularity of the VSD by offering a wider variety of models than in the past, and at a more affordable price.

Replacement. According to the Department of Energy, 6% of compressors are older than 20 years.[11] Our survey of end users with systems 100 hp and less showed an average age of 17 years. Half of the compressors from the survey were 20 years or older; 36% were newer than two years. Based on manufacturers' estimates of motor life, compressors are expected to last 15-20 years. At end of life, replacing older compressors with more efficient models may provide 10-20% savings. The average efficiency for new compressors is in the range of 91-95%, while older compressors are likely to be only 80% efficient. More efficient models do not necessarily mean that a smaller horsepower system can replace a larger system. Before attempting to reduce the system horsepower size, the system should be metered to determine actual air demands. Annual savings for replacing a low efficiency compressor may be up to 15%. The ultimate savings

[9] U.S. Department of Energy 1998b. *Improving Compressed Air System Performance: A Sourcebook for Industry.*
[10] Studebaker, Paul. *Compress Efficiently.*
[11] U.S. Department of Energy 2003c. *United States Industrial Electric Motor Systems Market Opportunities Assessment.*

potential varies depending upon operational hours and horsepower. Because of the cost of a new compressor, without an additional incentive, replacement for the sake of energy efficiency savings alone does not appear to be a cost effective option. Two scenarios are provided for comparison:

Annual electricity costs = (Motor full-load bhp) x (0.746 kW/bhp) x (1/efficiency) x (Annual hours of operation) x (Electricity cost in $/kWh) *(Source: CAC sourcebook)*

Table 9: Annual Electrical Costs Example 1	
A. One 50 hp compressor which runs 2,000 hours per year (1 shift)	
Efficiency	Annual Electrical Costs
80.0%	$9,325
93.3%	$7,996
Annual savings	$1,342 (14%)
Simple payback	12.5 years

* $16,750 Ingersoll-Rand 50 hp rotary screw compressor, $0.10/kWh, hp ≅ bhp

Table 10: Annual Electrical Costs Example 2	
B. One 75 hp compressor which runs 4,000 hours per year (2 shifts)	
Efficiency	Annual Electrical Costs
80.0%	$27,975
94.1%	$23,783
Annual savings	$4,192 (15%)
Simple payback	7.0 years

* $29,500 Ingersoll-Rand 75 hp rotary screw compressor, $0.10/kWh, hp ≅ bhp

Other Efficiency Measures. The efficiency options already discussed were widely agreed upon by stakeholders as the most promising opportunities for energy savings with small compressed air systems. In addition to these options, Cadmus reviewed the savings potential of other measures, such as engineered nozzles and advanced control strategies but found that, in general, these measures were not ideally suited for small systems and were not as cost effective as the measures discussed above. For this reason, lengthy discussion of these other measures is omitted here. For those interested, an overview of these measures and their potential savings for larger systems can be found in several of the sources cited in the References section of this report.

Program Recommendations

Present compressed air costs to end users when offering a program.

Of the end users surveyed for this report, only one person responded with an estimate of annual operating costs for compressed air. His $8,000 per year estimate was probably only half of the real costs for the 50 hp compressor. The Assessment of the Market for Compressed Air Energy Efficiency Services surveyed 222 end users of compressors 100 hp and above: 10% of whom indicated that they kept track of energy costs associated with the compressed air system.[12] When marketing an energy efficiency program, the utility may find it advantageous to present the amount of energy (and electrical cost) the system may be consuming, which would help to justify any additional investment in efficiency upgrades. A simple table like Table 11 could be used on marketing material to make this point to system owner/operators. In addition, a simple interactive calculator could allow customers to input number of compressors, size, and operational time and estimate compressed air energy costs. An advanced calculator could include a drop down menu for specific compressors to incorporate efficiency into the calculation. Though existing tools, such as Airmaster, allow these sorts of calculations, the available tools can prove daunting to some users and, for program marketing and education, a simpler calculator may prove more effective.

Table 11: Estimated Annual Costs of Compressed Air Systems based on operational time*

	1 shift – 5 days (40 hours per week)	2 shifts – 5 days (80 hours per week)	Constant operation (24/7)
25 hp	$3,730	$7,460	$16,350
50 hp	$7,460	$14,920	$32,675
75 hp	$11,190	$22,380	$49,000
100 hp	$14,920	$29,840	$65,350

** This is a simple cost estimate. Costs may be higher depending upon compressor efficiency. Cost calculated using $0.10/ kWh*

Advocate Leak Prevention Programs .

Leaks can be a major issue for systems of all sizes. Leaks are often addressed on an emergency basis, but rarely as part of a regular maintenance schedule. One program option is for the utility to purchase ultrasonic leak detectors and loan them to end users for little or no cost. This loan program could be used as a program hook to then follow up with the system owner with more information about leak repair and associated savings. According to the Compressed Air Challenge Sourcebook, a new user can be trained to use an ultrasonic detector in about 15 minutes. Along with the detectors, provide simple metering before and after the leak repair to quantify the energy savings. The Compressed Air Challenge organization estimates that a leak as small as 1/16" can cost $1,000 per year in wasted electricity.[13]

[12] Xenergy. Assessment of the Market for Compressed Air Energy Efficiency Services.
[13] *Costs calculated using electricity rate of $0.10 per kilowatt-hour, assuming constant operation and an efficient compressor.*

Install variable speed drives and/or additional receiver storage

While each application is considered unique, there are some appropriate opportunities for variable speed drive compressors that will provide end user energy savings; so too for adding receiver storage. The premise of these elements is to lessen the actual operational time of the compressor while still allowing it to function at optimum performance. The drawback is that these two options are not ideal for every system application. Much depends on the loading of the compressor.

Potential Program Barriers

- **Measures are not perceived to be cost effective at the small scale.** There is a perception on the part of the end user that making changes to their compressed air system would require significant capital investment, and may only yield modest energy savings. Even five year simple payback periods may be unacceptable, as interview findings suggest that most end users require a two year simple payback before considering system upgrades. Increasing awareness may help to address this issue by alerting system owner/operators of the high costs of inefficient compressed air operations.
- **Lack of awareness.** It has been well documented that most compressed air end users are not aware of the energy costs associated with the system, thus are not able to calculate savings from potential energy measures. This lack of awareness of compressed air cost may also extend to lack of awareness of new energy efficient features. If a system owner has an older compressor, their regular dealings with vendors may have subsided considerably, and they are therefore unaware of new system features and benefits. Targeted outreach describing system costs and the newest generation of efficiency upgrades, as well as any program incentives for those measures, may generate sufficient interest to overcome this lack of awareness. Providing these outreach materials to vendors/suppliers could reduce program marketing costs and put end users more directly in touch with potential suppliers of efficiency products and services.
- **Relying on vendor participation.** Since many of the savings revolve around operational use, (correct sizing, piping, correct usage) energy efficient solutions may lie best in the hands of compressed air vendors. The vendors are aware of energy efficiency much more than end users and have the ability (and often self-considered responsibility) to inform their customers of potential energy and cost savings measures. However, based on our vendor interviews and the Aspen study, there appears to be a split in vendor motivation.

Aspen describes the suppliers in the PSE&G Territory as being one of two types:

"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."

We spoke with several vendors who claimed that energy efficiency was something they offered to customers on a regular basis. In other cases, vendors were not concerned with energy efficiency, or with selling a smaller, more appropriate compressor. Their job is to sell compressors and make a profit doing so. Some vendors may have concerns that including efficiency in small system sales would add complexity to the sale and may thus decrease their own sales cost effectiveness.

- **Relying on efficiency savings from upgrading to new compressors.** Older compressors can cost end users money in lost efficiency, production down time to complete repeated repairs, and less production capacity. Compressors older than 20 years may be operating at an efficiency of 80% versus today's models, whose efficiencies are likely 90% or better. Despite this increased efficiency, energy savings alone are not likely to be a cost effective reason to upgrade a functioning compressor. Simple paybacks are likely to be five years or more; and most end users are looking to invest in a measure that will pay for itself within the next two years.

Estimated Potential Program Benefits

The cost effectiveness figures discussed previously assume system size and operating times at the upper range of what is typical for the small systems. However, the *costs* given are not directly related to system size. The cost to implement a leak detection program may depend upon the depth of the program: using an ultrasonic detector; frequency of inspections; etc. Due to this inelastic relationship, larger systems generally have better benefit/cost ratios for efficiency measures such as VSDs and leak detection/repair.

Table 12: Comparative Simple Payback of Efficiency Measures by System Size (yrs)

System Size	**1-25 hp**	**26-50 hp**	**51-100 hp**
Assumed Operating Time	**2,800 hrs/year**	**3,500 hrs/year**	**5,300 hrs/year**
Portion of Market (100 hp and smaller)	**60%**	**30%**	**10%**
Leak detection/repair (20% savings)	7.0	1.9	0.8
Variable speed drives (20% savings)	22.0	9.6	6.3

As shown in Table 12, systems greater than 50 hp offer the most cost effective savings because of their higher energy usage as compared to very small systems. This horsepower population represents about 10% of the units below 100 hp. Of these systems, the only major retrofit option that currently appears cost effective is leak detection/repair. A VSD is an attractive option to consider when purchasing a new compressor. However, as discussed previously, VSD compressors are not appropriate for all applications. Energy savings are possible from both options, however, any significant reduction in demand as a result of these options is unlikely. Table 13, below, summarizes the potential program benefits for leak detection/repair and VSDs.

Table 13: Program Annual Savings Opportunity

	Unit Savings (kWh)		Program Savings (MWh)	
Size	Leak Savings	VSD Savings	Leak Savings	VSD Savings
1-10 hp	4,178	6,266	612	918
11-30 hp	13,428	20,142	558	838
31-50 hp	26,110	39,165	258	388
51-100 hp	79,076	118,614	6,654	9,981

Next Steps

This study, to the extent possible, has provided an overview of the marketplace for small compressed air systems, as well as a broad estimate of potential energy savings for various prescriptive measures. The accuracy of these estimates is directly linked to the quantity and quality of the data received from primary sources (industry stakeholders and publicly available literature). The vast majority of this data is vague, generalized, or incomplete. One issue was adapting national trends and data to the Northwest region. It is also partially due to the highly specific nature of, for example, system energy consumption, that make “rules of thumb” and other generalizations difficult. Attempts at such generalizations, while necessary, produce an undesirable level of uncertainty around several key areas of these findings, as discussed in Table 14, below. In addition, Table 14 discusses some proposed actions that could reduce the level of uncertainty for each parameter. Based on the data available, it is not feasible, at this time, to make a quantitative estimate of the uncertainty in each result.

Table 14: Sources and Causes of Uncertainty in Study Results

Uncertain Result	Cause of Uncertainty	Action to Reduce Uncertainty
Measure savings	Lack of quantitative data in literature for small horsepower systems Market actors reluctant to make generalizations due to the variety of combinations of compressor size, run time and application	System modeling using Air Master or similar tool to estimate “typical” savings for several system configurations More detailed examination of available savings data for larger systems Re-contact manufacturers and consultants with more specific example systems to obtain better savings estimates
Measure costs		Re-contact manufacturers and consultants with more specific example systems to obtain cost estimates for measures

From the summary in Table 14, it is clear that room for improvement upon these findings is possible and, should additional accuracy be desirable (e.g. if a program plan is to be developed) there are a number of short term options to achieve this improvement.

Additionally, before a program is funded, it may be prudent to examine in more detail a number of program design options. For example, a second round of interviews could be conducted that focus on understanding reactions to particular programs as they are described to interviewees. This may be a better gauge of likely participation and overall success than the type of survey conducted for this market characterization study. Additionally this can be helpful, for example, when trying to understand the level of funding required to affect a change in purchasing policy or other behavior.

Conclusions

This market characterization study of the small industrial compressed air market in the northwestern US (Oregon, Idaho, Washington, and Montana) has illustrated a number of important findings relevant to the potential development of a utility program to support efficiency in this marketplace:

- There are about 15,000-17,000 industrial compressors, 100 hp or less, operating in the study region. About half of the system owners may have two or more compressors; often one of the additional compressors is kept for back up use only.
- About 1,000 new compressors are sold each year in the region. Roughly 75-85% of those compressors are 100 hp and below. Twenty to fifty percent of unit sales are for replacement compressors.
- Of these small systems, there are cost effective retrofit savings opportunities for some systems at the upper end of the small size range (i.e. 51-100 hp). These potential savings are heavily influenced by system run times. The cost effectiveness of measures for systems smaller than 50 hp, or with little operating time, is questionable.
- A potential program to improve efficiency in this market will have to overcome significant barriers such as marginal cost effectiveness and low awareness of system energy costs. If these can be successfully addressed, potential savings might be as high as 16-28 million kWh annually.

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Appendices

Appendix A: Interview Feedback
Appendix B: Literature Review
Appendix C: Survey Instruments

Appendix A: Interview Findings

General

- Systems less than 50 hp were considered to be “small” systems by most interviewees. The manufacturers interviewed reported strong demand for small industrial compressed air systems and indicated that those formed the majority of their air compressor sales. All of the manufacturer representatives were knowledgeable regarding energy efficiency measures and how those were integrated into their products. Some of the reps were also very enthusiastic about energy efficiency and claimed a large focus on educating consumers and/or distributors regarding measures and cost savings. A variety of important energy efficiency measures were described, with VFDs, storage tanks, and leak repairs representing the widest consensus of opinion. Many of the prescriptive measures listed in the survey were met with hesitation due to cost concerns in relation to the scale of small industrial compressed air. There was not a uniform solution reported for determining incentives. When planning the prescriptive measures to be introduced, it may be wise to include representatives from several key vendors to help develop a program with which they will actively participate.

Manufacturers

- Many of the leading manufacturers represented in the Northwest sell directly to end users and claim to put an emphasis on marketing energy efficiency to end users. Compressed air manufacturers have been working to design more energy efficient equipment, but none of our interviewees indicated that any radically new technology is expected to be introduced in the next five years. (Note: a member of the task force says that Atlas Copco is releasing the next refinement of their screw element next month.)

Distributors/vendors

- Since many of the savings revolve around operational use, (correct sizing, piping, correct usage) energy efficient solutions may lie best in the hands of compressed air vendors. The vendors are aware of energy efficiency programs much more than end users and have the ability (and often self-considered responsibility) to inform their customers of potential energy and cost savings measures.

Users

- End users are primarily concerned with consistent daily operations and less about long term or even short term savings from energy conservation. If they are aware of potential improvements, there is little time to seek out root causes of efficiency problems, and even less time to search out funding for these measures. Any interest in potential energy saving measures is somewhat proportional to the horsepower size of the system. A large part of an effective program will be educating the users on the value of attending to compressed air as a utility and then providing a simple program that adds value to their daily operations and annual bottom line.

Utility Program Managers

- Utilities in the Northwest have a long history of providing programs to achieve energy efficiency for compressed air; participation, however, has typically been low. Emphasis has been on large horsepower systems where more significant energy savings could be achieved. The utility program managers interviewed indicated that one of the keys to a successful compressed air efficiency program is having a strong base of vendors who are educated and enthusiastic in regard to energy efficiency, since the vendors have significantly more direct contact with end users. The program managers also noted that vendors rarely put much effort into promoting energy efficiency. Recommendation: Promotion is OK, but as a program operator, you must do the work of thinking out in detail how you are going to get from idea to an actual on-the-ground change in either equipment or behavior.
- While many utilities have programs related to small industrial compressed air systems, there appears to be little internal support for them. Most utility program managers are aware of the issue and some potential solutions, but have limited time or resources to devote to more comprehensive solutions. The utility participants surveyed would like to develop more effective programs, but believe those programs need to engage vendors to more actively participate to be most successful. The utilities rely on vendors to recruit customers to the programs, communicate incentives and then assist customers through the complete process. The utilities could offer a variety of free technical services, such as leak audits and/or leak detector loan programs, to draw more customers in and educate them about their energy efficiency options. The major concern expressed is that prescriptive measures represent too much of an up front cost hurdle for customers to participate, despite the incentives being offered. Consider the process: What is it like for the user?

Interview Findings-Manufacturers

Market Data

- Systems less than 50 hp were considered to be “small” systems by manufacturers
- The quantity of small horsepower systems sold (less than hp) far outnumbers larger systems. Compressors 100 hp and smaller represents 75-85% of the industrial market. Compressors 50 hp and smaller represents approximately 60% of the industrial market.
- Rotary screw is the single most common compressor technology for small industrial systems. Reciprocating machines are mainly used on “light commercial” in the range of up to 20 hp; most prevalent 10 hp and below.
- It is estimated that there are currently around 15,000-17,000 small compressed air systems operating in the Northwest.

- The overwhelming leader in the Northwest industrial compressed air market is Rogers Machinery. Atlas Copco is second, closely followed by Sullair. While manufacturers were not highly forthcoming with actually sales figures, Rogers estimates its share of the market to be 60%.
- Most manufacturers experience the bulk of their sales in Washington State, with Rogers Machinery controlling more of the market in Oregon. Idaho and Montana usually represented the smallest proportion of sales in the region.
- The typical base package for a new installation would typically include load/unload controls, and almost all systems will have receivers (storage tanks) sized around 1 gallon per CFM, and most use refrigerated air dryers. Some manufacturers indicated that many new systems will have VFDs, but it often depends on the application. *(Note: conflicting evidence was found for the number of VFDs actually installed.)*
- An analysis of basic compressor costs shows that compressors between 50 and 100 horsepower cost between $350 and $450 per horsepower. *(Note: this cost will depend upon a variety of factors including manufacturer, supplier, storage, and other add-ons.)*
- There are a variety of applications for small compressors; too many for most manufacturers we interviewed to describe thoroughly. Replacement of compressors was estimated to be 20 to 50% of sales; the remaining sales are for new applications (plant expansion considered as new). However, these portions vary widely by manufacturer.
- Supply Chain: Most of these manufacturers sell directly to customers, although some do have a small portion of “Tier 2” dealers. For example, Sullair relies entirely on Dickinson Equipment as their distributor, and Dickinson’s relative strength determines Sullair’s market share in the Northwest.

Manufacturers’ Perspective on Energy Efficiency:
Optional features that are used in compressed air systems:

- Variable Frequency Drive compressors (VFDs) are currently a very popular type of compressor capacity control. VFDs have a high incremental cost, (10-50% more than a non VFD compressor) but provide good energy savings as well as lower maintenance costs. Less wear on the drive system and bearings results in longer life for the compressor. There is still resistance from customers due to the high cost.
- Some examples of VFD pricing (and CFM range):
    - V15 (10-50): $14,000
    - V25 (10-107): $18,000
    - V50 (35-247): $25,000
    - To select receiver size, choose size of compressor, for example a 50 HP VFD unit. The system would operate at around 250 CFM in fast mode and around 50 CFM in slow mode. The receiver should be sized around 5 gallons per CFM in slow mode (5 x 50 = 250 gallons of receiver storage).
- Increased storage capacity (air receivers) were also cited as an efficiency option by most, at a cost of about $6 per gallon (per Vendor interview)
- Example pricing:
    - Receiver pricing:
    - 400-gallon - $2,100
    - 600-gallon - $4,600
    - 1,060-gallon - $5,900

- Miscellaneous efficiency measures cited by manufacturers were: purge control, low pressure drop filters, flow controllers, mechanical variable capacity control, and shut down timers.
- Sullair was very big on mechanical variable capacity control, although very few manufacturers provide this option for larger systems. The smallest compressor sizes for which Sullair offer s the mechanical variable capacity control is currently in the range of 60 to 75 hp. Apparently the most effective use is allowing VFDs operate in a wider range of environments. Perhaps this is a measure to keep an eye on in the future. Caution... those valve or port-based capacity control mechanisms often aren't adjusted right.
- Opinions vary widely on measures suitable for retrofit. Some stated purge controls for dryers as well as additional receiver capacity. VFDs and zero loss drains could be too difficult and expensive to retrofit, particularly for small systems. Retrofitting a VFD is troublesome and risky. In VFD compressors, the screw element has been specifically designed for the speed range at which the controls will operate it. Details of lubrication and part-load efficiency and throughput make this a difficult task. Hence adding a VFD to an existing compressor is rarely done.
- The greatest opportunities for savings are VFDs and fixing leaks. One manufacturer also suggested shutting units down after hours as a savings opportunity.
- All manufacturers had attended Compressed Air Challenge trainings, but none use AirMaster for analysis of small industrial compressed air systems. Most have in-house software that they consider superior to AirMaster.
- All manufacturers interviewed provide education and training to customers and/or vendors, as well as assistance in designing an optimum system. The training often resembles that provide by Compressed Air Challenge, with a focus on energy efficiency, as well as maintenance and operations. The design assistance will often include baseline metering, engineering support, audits, leak surveys, and post-install data logging.

Manufacturer Suggestions for Utility Programs (How they would be best engaged by a program)

- On the surface compressor manufacturers would seem the least likely to be engaged in an energy efficiency program. They see their role primarily as delivering value to their customers, and in doing so, design their compressors for reliability and increasingly so now, for energy efficiency. However, the manufacturers surveyed expressed real interest in other energy efficiency measures, yet were realistic in suggestions of implementation.

- In terms of utility-funded programs, the only real agreement was that there was *no interest in utility incentives on a per horsepower basis for small systems*. Some of the manufacturers were very happy with ETO's current air compressor efficiency program. One manufacturer stressed that the prescriptive measures listed were simply not cost effective and appropriate for the small industrial systems, and noted that market transformation is already being achieved on some elements, such as VFDs. Additional ideas that were thrown out include:
  - Additional receiver storage (About $6 per gallon)
  - Incentives would be based on a percent of overall cost. Or, to keep incentive levels tied to energy savings as they are now.
  - Incentives for leak detection and repair.

- Most manufacturers believed that the customer does not need site specific savings numbers to make a decision. Most will want some information, but the compressor salesperson is the key – if that person can convey the value proposition of an energy efficient system, then that would be enough to make the sale. Auditing and data logging can be provided after installation to demonstrate the value provided.

Interview findings – Distributors/Vendors

- According to one vendor, significant effort has been put into outreach and education on energy efficiency already. Most vendors replied that they offer their customers energy efficient options such as audits; variable speed controls (as appropriate); and maintenance contracts. However, the end users, when surveyed replied that vendors are not mentioning energy efficiency.
- A lot of the low-hanging fruit on VFDs has already been picked, that market is slowing down, according to some manufacturers.
- Distributors believe that many of the remaining end users either don't want to deal with program bureaucracy or simply don't want to spend the additional money on more energy efficient equipment. They anticipate that it would be tough to pursue further rebates in this area.
- One suggestion for a prescriptive utility program is to offer an incentive for additional air receiver capacity. He suggested the utilities set a prescribed gallon/CFM level, and then cover 50% of the cost to achieve that level, while ensuring the application process is as streamlined as possible.
- Feedback regarding current programs included that vendors have seen utilities start out with great, accessible programs, then tighten them up to the point where it's too difficult to participate, and then eventually drift back to a middle ground as they see participation wane.
- There's been movement away from energy audits, because most people have already had them performed. Vendors estimate that data logging is currently performed on about 10% of all systems sold.
- Vendors estimate that 20 to 50% of their small compressor sales are for replacement of old compressors; and many customers upgrade to energy efficient systems.
- The overwhelming majority of the vendors interviewed said that systems were almost always oversized. This is due primarily to the fact that the customer does not always correctly understand or communicate their actual use. Additionally, many vendors like to provide room for system growth.

Interview findings – Consultants

- Almost all consulting studies are on existing systems, and not design for new systems. Many of the consultants interviewed have worked in California, in addition to Oregon, Washington and Idaho. Most agreed that systems below 100 hp were not cost effective

targets for engineering studies. The value of the energy savings is not generally high enough to warrant the cost of a complete investigation.
- While the consultants estimated that their company's industrial air effort was anywhere from 15 to 90% of their *total* work, less than 15% of that compressed air work was with systems 50 hp or below.
- One consultant suggested that the market for industrial compressed air is shrinking as the US industrial market becomes smaller due to off-shoring.
- Data logging is not a cost effective option for small systems.
- A primary observation is that small system owners do not have the time or the maintenance staff to inquire about available energy efficiency programs and investigate their own issues. Small system owners also don't want to lose staff to all day training. Most owners will not even know if there system is operating less efficiently than it should. Additionally, there needs to be a shift away from thinking that compressed air is free. Rising energy costs should help raise awareness, but ongoing marketing and training efforts should continue.
- Other barriers include varying knowledge of vendors who make system recommendations.
- One consultant phrases the barrier to working with small systems in the following way: "It is the high cost of engineering investigation, including the appropriate performance measurements need to accurately diagnose a system's problems, that is the barrier for most small systems."
- Having the utility recruit the customer to work with a consultant brings a level of trust.
- Many suggest customer-specific solutions that would seem to discourage a prescriptive approach, but most believe that a simple prescriptive approach would be the best for the end user. An example for such an approach might be:
  - 50 hp system * 0.746 kW/ HP * (4380 hours/year) * 50% of the time = 164,000 kWh annual energy use
  - Estimating system savings of 30% = 49,000 kWh saved
  - $2,450 annual savings (at $0.05/ kWh)
  - Cost of implementation: $4,000 for study + leak detection, repairs, etc…
  - The longer a machine runs, the more cost effective the savings become
- One consultant estimated an energy investigation would cost $0.06 per kWh saved
- Barriers include the fact that many solutions must be customized, even at the small system level. The energy savings available at that level would not cover the cost of the study.
- All consultants were familiar with Compressed Air Challenge training. Some had facilitated trainings of their own as well.

Interview findings – End Users

Table 13: Examples of Individual End User CA Energy Use				
hp	Estimated daily Operational Time (hours per day)	PSI	Annual kWh	Estimated annual energy costs (calculated $0.10/kWh)
2	9	110	3,491	$350
5	12	100	11,637	$1164
7.5	6	110	8,728	$872
10	12	110	23,275	$2,328
20	2	125	7,758	$776
30	2	125	11,637	$1164
50	17	100	164,866	$16,486

- Most small compressed air end users do not have a staff member responsible for energy efficiency; nor does the organization have an energy management plan.
- There were few respondents who could estimate annual compressed air operating costs, although the accuracy of the estimates that were provided must be questioned. One end user estimated that compressed air represented 50% of his energy costs, while another put the estimate at 2%.
- Routine maintenance includes draining water, changing oil, cleaning heat exchanger and change the air filter every 100-250 hours or once or twice per year.
- System age ranged from six months to fifty years.
- Most end users interviewed had compressors which ranged from 2 to 10 hp; a few as high as 40 or 50 hp.
- System pressure was between 100-125 psi.
- All end users surveyed intend to continue use of compressed air for at least the next five years and have no plans to replace compressed air with an alternative.
- A significant barrier to implementing new measures involves the time to shut down a production line long enough to upgrade a compressor

Interview Findings – Utility Program Managers

- Currently several utilities in the Northwest have active programs for the industrial compressed air sector. They have all been active for some time, with varying degrees of success. The programs are primarily geared toward systems larger than 100 hp and require detailed measurement and evaluation processes that are typically too involved to be cost effective for small systems.

- **Overall Program activity:** Participation was rather low, particularly for compressed air systems, and presumably scaled according to the size of each utility's service territory. Tacoma Power had seven program participants in 2007 and three so far in 2008. PSE estimated that they implemented 20 to 50 projects per year. Pacific Power estimated 20 projects per year for their service area in Washington State – their territory in Oregon falls under ETO jurisdiction and their program was just approved for Idaho. The estimated overall program participation for small compressed air systems was very low. We would have liked to examine the energy savings by compressor size for this research, but the information was not available in the evaluations reviewed. .

- **Barriers:** A variety of barriers were presented for **program marketing** for small compressed air systems.
    - The primary barrier was lack of utility interest in aggressively marketing a small compressed air program to end users. Utilities must contend with the issue of reduced payback for small companies who are already paying relatively little for electricity in the Northwest.
    - The utilities also have less direct interaction with end users in regard to energy efficiency, and rely instead upon vendors. There is also a lack of information reaching the customers.

- The barriers to successful **program implementation** share several of the above concerns. Since the vendors are the primary parties involved in controlling communication and information for the end user, utilities must construct programs which can be implemented through vendors. Vendors were consistently identified as the most important factor in the success of compressed air programs. Without educated and enthusiastic vendor support for energy efficiency, projects will not be submitted to the program. Limited time, lack of marketing support, and inconsistent processes were also cited as barriers to successful implementation.
- Most of the utilities, except PSE, conduct detailed monitoring and verification studies to verify savings. The results have typically been close to initial savings estimates. Pacific Power offers a potential exemption on commissioning for the small compressed air systems, at the cost of a 20% incentive reduction. In many cases for small systems, the commissioning cost exceeds the 20% incentive reduction so that represents a better deal for the small system owner.
- Advice for other utilities: several of the program managers interviewed suggested that the most important aspect would be to build strong relationships with engaged trade allies. The utilities suggested that this could be more cost effective and time saving by focusing each utility's marketing power. Another utility also suggested going beyond each site's plant engineering and facilities staff, and try to reach the decision-makers who control capital funding. There were also suggestions to increase the amount of money offered for the program, as well as offer free leak audits and demand side assessments.

- Training and educations: Most of the utilities piggybacked on trainings offered by the Compressed Air Challenge and the Northwest Energy Efficiency Alliance. These trainings were apparently fairly successful and well-attended, particularly when the utility paid the fees for their customers. All of the utility program managers had good experiences with the Compressed Air Challenge. The Level I training was generally deemed to be the best and most applicable to their customers.

- The utility program managers tended to view VFD compressors as the most substantial opportunity for energy savings. Increasing receiver capacity was also viewed as important. One utility focused more on leak repair and pressure optimization.

- Of those interviewed, only Pacific Power required a trade ally program in order to qualify for the program incentive. A trade ally is a recognized contractor or distributor who is affiliated with the utility program. Other programs simply had basic requirements that a contractor must meet to install the measures and to perform assessments.

Appendix B: Literature Review Results

The literature review, which included the review of over 50 publicly available documents and studies, provided the following key points:

- Industrial compressed air systems have been extensively studied nationwide and at the regional level. A number of utilities nationwide have implemented energy efficiency programs for compressed air systems with mixed success. It is generally agreed that energy efficiency measures for large compressed air systems (greater than 200 hp) offer cost effective and attractive energy and cost savings. Large systems have thus been the focus of many consultants and many utility programs. Smaller compressed air systems, less than 100 hp, have been generally omitted from study by consultants. Consultants acknowledged that studies which include system monitoring of small and large systems can be comparable, yet the savings potential for smaller systems does not always justify study costs.
- Over the last several years, there have been claims of better energy efficiency and better controls and system monitoring. Current technology is more efficient that their counterparts of 20 years ago, but there have not been any major changes in technology.
- There are some major distinctions between the findings of this study and those of prior studies. Primarily the energy savings that exist from efficiency of larger horsepower systems seem to be unproven at a small scale. In most studies which focus on systems larger than 200 hp, interviewees are much more interested in energy efficiency and implementing cost saving measures. For example, the EERE study interviewed end users who had purchased energy efficiency service to determine the reasons for the purchase. In the case of the interviews for this study, none of the fifteen end users had purchased *any* energy efficiency services. Additionally, slightly over a quarter of the EERE study participants had a staff member trained in compressed air system efficiency, while only one organization in this study had sent someone to training. A similarity between this study population and that of previous studies is the commonality of barriers to implementation of energy efficiency. Lack of time among maintenance staff as well as competing priorities – daily operations take precedence – are common regardless of company size and compressor size.

Utility Program Descriptions

Tacoma Power: Tacoma Power's program offers CAC training for end users and vendors; rebates for energy efficient equipment; and assessments for both demand-side (leak detection) and supply-side. For Tacoma Power, a customer is first required to submit to a demand side assessment to evaluate leaks. Tacoma Power covers half of the cost of this assessment. The customer is required to fix high priority leaks and then submit to post-monitoring. A post-leak baseline is established and energy savings estimates are provided before incentives for equipment upgrades are allocated. The vendor must then provide a supply side assessment and post-installation monitoring to verify savings. The customer is further required to survey for leaks once each year. According to our interview with Tacoma Power, to improve the rate of small industrial compressed air participation, the demand side assessment was eliminated for projects under 75 hp. (http://www.tacomapower.com/Business/compressed_air_program.htm)

Puget Sound Energy: PSE's program is a more custom approach to compressed air system upgrades. PSE performs a project analysis, showing energy and cost savings and then evaluates the eligible grant amount on a project by project basis. They then verify the installation before refunding the customer. (http://www.pse.com/SiteCollectionDocuments/business/3341_RetrofitFinal.pdf)

Pacific Power: In Oregon, Pacific Power runs efficiency programs through the Energy Trust of Oregon. (See details below) In Washington, the program name is Energy FinAnswer. There is no horsepower minimum, just a square footage (20,000 feet) per meter minimum to be eligible to participate in the program. These programs appear more custom in nature. The utility works with the customer to identify energy saving opportunities, then provide a vendor-neutral analysis to support the customer's decision making process. There is a post installation calculation of annual energy savings.

PGE: The following comes from an interview with PGE: Customer would sign an agreement saying that they would implement audit suggestions up to a certain cost. A consultant would do an assessment of the facility and identify areas of improvement. A second assessment would be completed at a later time to quantify the energy gains. There was a lower horsepower limit to participate.

Seattle City Light: The program has several parts: A rebate program for replacement compressors with variable speed drives (less than 50 hp). They claim that VSD control is more efficient than load/no-load controls, which are more efficient that the modulating controls on the unit being replaced. There is also a bonus for replacing desiccant dryers with refrigerated dryers in existing facilities. Or replacing existing desiccant dryers that use electric resistance heat with heat-of-compression desiccant dryers in new or existing facilities. A third part of the rebate addresses alternative uses for compressed air. The rebate will fund the conversion of industrial equipment from compressed air to direct drive, which they estimate will save up to 80%. Appropriate applications may be cooling, drying, conveying, mixing and cleaning. Finally they offer a bonus for replacing baghouse compressed air controls with controls that issue pulses based on measurement of the differential pressure across the bag filters. The new air compressor must be 35 hp or less; new water drains must be zero loss or not "timed;" and air leaks must be repaired to earn the full rebate. City Light uses a hand built spreadsheet to total customer costs and the calculated energy savings as part of the rebate application. (http://www.seattle.gov/light/conserve/business/cv5_cw.htm#compressed)

Energy Trust of Oregon: ETO currently offers programs targeting small and medium sized manufacturing facilities as well as larger industrial facilities. For single compressor systems less than 50 hp, ETO will refer the customer to one of their five trade allies, compressor distributor, for an energy efficient compressor replacement.

They offer a cash incentive of $0.15/annual kWh savings. (http://www.energytrust.org/pe/manufacturing.html) For larger systems, ETO works through three program delivery contractors (PDCs) who will perform energy audits at no cost to the customer and help facilitate the rebate process. (http://www.energytrust.org/pe/industrial.html)

Appendix C: Interview Guides

Equipment Manufacturer Interview Guide

Market & Sales Overview Questions

1. What horsepower range would you use to define "**small**" compressed air systems for industrial applications?
2. If known, what portion of your company's **annual industrial unit sales** falls within the following horse power ranges?

HP	Sales %
0-5	
6-25	
26-50	
51-100	
>100	

3. Within the range of small industrial compressors, how are your sales divided by state:

State	Sales %
Idaho	
Oregon	
Washington	
Montana	

4. What is the most prevalent **type of compressor** for small industrial applications?

Type	Notes
Reciprocating	
Rotary Screw	
Centrifugal	
Other (specify)	

5. For small compressors that you sell, what does your typical base package for a **new installation** include?
   a. What type of controls come standard? (load/unload, VFD, etc.)
   b. Is a storage tank included? What size? (gallons/cfm)
   c. Is a dryer included? What type? (refrigerated, heatless, heated, etc.)

6. What portion of small compressor purchases are for replacement, plant expansion, and new installations?

	Sales/ Notes
Replacement	

Plant Expansion	
New	

7. How many small industrial air compressors do you estimate are sold by your company in Idaho, Washington, Montana and Oregon on an annual basis? *(regional sales data)*

State	**Sales/ Notes**
WA	
OR	
ID	
Montana	

8. Where does your company rank in terms of sales of small compressed air systems, compared with your major competitors, in Idaho, Washington, Montana and Oregon? *(market share)*
9. How many small compressed air systems would you estimate are **currently in operation** in Idaho, Washington, Montana and Oregon?
10. Who are the major distributors that you work with in Idaho, Washington, Montana and Oregon?

Energy Efficiency

11. What sort of **optional features** or equipment that could be used to improve the **energy efficiency** of small compressors do you offer, if any? How often do customers opt to purchase them with new compressor? (% of sales?) What is the percentage added **cost**, to a base compressor package, of these efficiency features?

Feature	% sales (customer demand)	Additional Cost

12. Do you actively **promote** these energy efficiency features to your customers? Why or why not? What methods do you use to promote the features?
13. How often are the following measures used? i.e. What sort of demand do you see for these measures?

Prescriptive Measure	**Customer Demand**

Low pressure drop filters	
Cycling refrigerated dryers	
Purge control on dessicant dryers	
receiver capacity addition	
zero loss drains	

14. If a utility were to develop a prescriptive program around these measures what if any concerns would you have? What other measures be considered for prescriptive rebates?

Prescriptive Measure	**Specific Concerns**
Low pressure drop filters	
Cycling refrigerated dryers	
Purge control on dessicant dryers	
receiver capacity addition	
zero loss drains	
Other measures	

15. If you collect data to inform your recommendations, what data do you collect and how?
16. Which, if any, of these features are field installable as a means to reduce a compressed air system's energy consumption *after* the initial equipment purchase? (System retrofit options?)
17. Who if anyone, typically approaches your company with questions or concerns related to energy efficiency?
18. What do you view as the most substantial opportunity for energy savings in small compressed air systems?
19. What recommendations would you have as to how to structure a **Utility** funded incentive program to best address these opportunities for cost and energy savings?
20. Would you preference be equipment based incentives, where the incentive is $/hp or $/unit?

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21. Do you believe the customer needs site specific savings numbers to make a purchase decision?
22. Do you use AirMaster? Would you use it for small compressed air system projects? Would you use a simplified analysis tool (such as one in Excel) provided by the program to provide savings estimates to your customers?
23. Have you or any of your staff recently (last 2 years) attended Compressed Air Challenge training? _____yes ______no
24. Do you provide **education or training** to your distributors or customers to help them identify energy savings opportunities? Can you describe this training?

25. Do you assist customers with **designing/optimizing** air distribution systems when you sell them a small compressor?
    a. What types of support do you offer? (eg: sub metering of compressed air performance?)
    b. If not, what are major barriers?

26. During this process, we are constantly learning more and refining our understanding of the compressed air marketplace. Would it be all right for us to contact you with follow up questions, should they arise, at a later date? Yes ____ No ____

27. Based on the conversation we have had today, is there anyone else that you would recommend we speak with to better understand the small industrial compressed air marketplace and technology?

Market & Sales Overview Questions

1. What portion of your business is related to industrial compressed air systems? (What other products, if any, do you represent?)
2. Who are the major manufacturers that you work with?
3. What horsepower range would you use to define "**small**" compressed air systems for industrial applications?
   Note that we will be focusing on small systems for many of the questions.
4. About what portion of your **annual industrial unit sales** falls within the following compressor horse power ranges?

HP	**Sales**
0-5	
6-25	
26-50	
51-100	
>100	

5. Within the range of small industrial compressors, how are your sales divided by:
   a. State

State	**Percentage of Sales**
Idaho	
Oregon	
Washington	
Montana	

6. What is the most prevalent **type of compressor** for small industrial applications? Do you foresee any new technologies that will be making an impact on the small compressed air market over the next 5 years?

Type	**Notes**
Reciprocating	
Rotary Screw	
Centrifugal	
Other (specify)	
New Technology	

7. How have sales of small compressed air equipment changed in the last year? Five years? Are there any noticeable trends?

8. For small compressors that you sell, what does a typical base package for a **new installation** include?
   a. What type of controls come standard?
   b. Is a storage tank included? What size?
   c. Is a dryer included? What type?
9. What are the standard applications for these small compressed air systems? Are there certain industries you sell more to than others?
10. What portion of small compressor purchases is for replacement, plant expansion, and new installations?

	Percentage/ Notes
Replacement	
Plant Expansion	
New	

11. How many small industrial compressors do you estimate are sold in Idaho, Washington, Montana and Oregon on an annual basis? *(regional sales data)*

State	**Sales/ Notes**
WA	
OR	
ID	
MT	

12. Where does your company rank in terms of sales of small compressed air systems, compared with your major competitors, in Idaho, Washington, and Oregon? *(market share or rank)*
13. How many small compressed air systems would you estimate are **currently in operation** in Idaho, Washington, and Oregon? How did you arrive at your estimate?

Energy Efficiency

14. Do you offer **optional features** or equipment that improve the **energy efficiency** of small compressed air systems? ____Yes _____No

15. What are those optional efficiency features, and how often do customers opt to purchase them with their new compressors?
16. What is the estimated cost range of these additional efficiency features?

Feature	Estimated Cost	Details

17. Do you actively **promote** these energy efficiency features to your customers? Why or why not? What methods do you use to promote the features?
18. Which, if any, of these features are field installable as a means to reduce a compressed air system's energy consumption *after* the initial equipment purchase? (System retrofit options?)
19. What kind of customers, if any, approach you with questions or concerns related to energy efficiency for small systems?
20. What do you view as the most substantial **opportunity for energy savings** in small compressed air systems?
21. What recommendations would you have as to how to structure a **Utility**-funded program to best address opportunities for energy savings?
22. Do you provide **education or training** to your customers to help them identify energy savings opportunities? Can you describe this training? Does it apply to small systems?
23. Do you assist customers with **designing/optimizing** compressed air systems? Is the level of assistance the same for small compressed air systems?
    a. What types of support do you offer?
    b. If not, what are major barriers?
24. When selecting a compressor for an application, what safety margin, if any, do you apply to the customer's estimated compressed air load? Do you apply this margin to small systems?
25. Would you say that most compressed air systems are correctly, over, or undersized?"
26. Do you use any data logging tools to estimate energy savings? How often are they used? Are they used on small systems as well?
27. During this process, we are constantly learning more and refining our understanding of the compressed air marketplace. Would it be all right for us to contact you with follow up questions, should they arise, at a later date? Yes ____ No ____
28. We would like to contact end users of compressed air. Do you have any customers who are currently using small industrial compressed air in their facilities? If so, would you be willing to share contact information for that customer?

Utility Program Manager Interview Guide

General Questions

1. What has been the utility's experience in the industrial compressed air sector?
2. Have you already tried to implement a program for industrial compressed air systems efficiency? ______ Yes ______ No
    - Is the program currently active? ______ Yes ______ No
    - Is there a website or other resource available that we could review to learn more about the program?
    - Can you provide a brief overview of how the program works or worked?
    - How many customers have participated? (Cumulative? Per year?)
    - What portion of your program resources would you estimate is devoted to compressed air systems less than 50 HP total? Less than 100 HP?
    - What, if any, barriers have you identified to <u>marketing</u> for this program to end users?
    - What barriers do you think your <u>customers</u> have to implementing compressed air efficiency measures that could provide energy savings? Are these barriers any different for small systems?
    - What, if any, have been barriers to successful <u>implementation</u> for the program?
    - Again, are these barriers any different for small systems – for example, less than 50 HP compressors?
    - Have you conducted an evaluation of your compressed air program(s)? If so, what were the findings of those evaluations? Are the evaluation reports available for review?
    - How do you determine the cost effectiveness of your supported measures? Do you use prescriptive savings estimates or customized analyses for each situation? Could you share any of these data or assumptions with us?
    - Have you conducted any monitoring and verification studies on customers participating in your compressed air program(s)? If so, what have the findings of those studies been?
    - Who would you consider to be the top compressed air market leaders that can affect the success of compressed air programs? Vendors? Consultants? Etc. What advice would you offer to other utilities that might undertake a similar program?
3. What types of program initiatives or options have you found to be successful for similar programs? For example – offering system audits? Training? System leak detection and repair? Incentives towards energy efficient measures in addition to efficient air compressors? Correction of distribution issues or change out of inappropriate end-uses?
4. Do you currently offer or promote any training on energy efficiency for compressed air systems?
5. What do you view as the most substantial opportunities to reduce energy use in small compressed air systems?
6. What has your experience been with the Compressed Air Challenge program (CAC)?
7. Would customers need to use the services of approved trade allies in order to qualify for the incentives? If so, how are these allies selected? Do the partners participate in additional training or meet other special criteria?

End User Interview Guide

How they view energy use?

1. Which of the following policies or procedures does your organization have in place regarding energy efficiency improvements at this facility? *(Check all that are mentioned, do not probe.)*
   - ❑ An energy management plan
     (If have plan, does it have numerical goals?
     - ❑ Yes ➔ What are the goals? ______________________________
     - ❑ No
     - ❑ Don't know
   - ❑ Staff member responsible for energy and energy efficiency
   - ❑ Corporate Policies that incorporate energy efficiency in operations and procurement
   - ❑ Other (e.g. active training of staff etc.)

What % of energy use CA is?

General Questions

2. How many air compressors do you have at your facility? Are any standby or backup units? And about how long do each of the compressors run?

	# of compressors
Primary units	
Standby	
Total	

3. What type and size are these compressors?

Type	Size (HP)	Notes
Reciprocating		
Rotary Screw		
Centrifugal		
Other (specify)		
New Technology		

If more than one compressor:
   Used as system? (if multiple systems please describe?)
   Controls Yes no what type?

4. About how old is your compressed air system? Have any major changes or replacements have occurred since it was installed? If so, why?
5. In addition to the air compressor(s), does your system include any of the following components:
   a. Dryer
   b. Receiver tank
   c. Filter
   d. Heat recovery unit

6. What is compressed air used for at your facility?
    a. Pneumatic tools (air motors)
    b. Air conveying
    c. Pneumatic controls
    d. Purging
    e. Painting and/or sand blasting
    f. Welding/ Cutting
    g. Other

7. Have you considered, or are you considering, alternatives to compressed air for any of these applications?
    a. Do you foresee your continued use of compressed air for the next 5 or more years?
8. Do you know the pressure at which the compressors typically operate?
9. How was the system sized?
    a. Was it designed specifically for this application? _____ Yes ______ No
    b. Have compressors been added over time in order to meet increased demand?
    c. To your knowledge, does the system include any energy saving features such as low pressure drop filters or an oversized receiver tank?

10. Who are the major suppliers that you buy compressed air equipment and services from?
    a. Have your suppliers made you aware of energy efficient options?
    b. Have they talked to you about training for compressed air efficiency?
11. Has there ever been an audit of the compressed air system – look for air leaks, etc.
12. How long does your compressed air system run, hours per day? Days per week?
13. Is your system typically shut off when not in use, like at night and over the weekend?
14. Could you estimate your annual compressed air operating costs? (Energy costs, maintenance, labor?)

Maintenance Questions

15. Can you describe the routine maintenance that you perform on your compressed air system?
16. Approximately how much money do you spend annually to perform maintenance/upkeep on your compressed air system?
17. Do you have any programs or procedures to regularly detect and repair compressed air leaks?
18. Are there maintenance activities that, to your knowledge, are not performed as regularly as they should be? If so, why?
19. Is there someone at your site who is responsible for the maintenance and performance of the compressed air systems?
20. Does this person, or any other employee, regularly attend (or have ever attended) training regarding proper maintenance and operation of compressed air systems?

Energy Efficiency and Utility Program Questions

21. How important do you consider energy efficiency in relation to your compressed air system?
    a. Very important
    b. Somewhat important
    c. Not important
22. What steps do you currently take or have you taken in the past, beyond routine maintenance, to improve or maintain the energy efficiency of your system?
23. Does your system include any recent upgrades, such as VFDs, engineered nozzles, or other measures intended to reduce compressed air use and/or energy consumption?
24. What are your most significant barriers to better system maintenance and the installation of energy saving equipment/features for your system?
25. If a utility were to offer an energy efficiency program aimed at compressed air, what program features would induce you to participate? What program features/requirements would make it difficult for you to participant? What could a Utility provide that would best enable you to improve the efficiency of your compressed air system?
26. If a Utility were to offer you an incentive to upgrade or perform more comprehensive maintenance on your system, with attractive potential energy savings, how likely would you be to participate if participation required a few hours of staff time to fill out paperwork and implement the measures?
    a. Very likely
    b. Somewhat likely
    c. Not likely

Survey results: Question #26 End User Willingness to Participate in a Utility incentive Program	
Willingness to participate in energy efficiency program	Respondents Agreeing
Very Likely	13%
Somewhat Likely	47%
Not Likely	40%

27. What amount would you be willing to invest in energy improvements in order to save on your annual energy bills?
    a. What kind of payback would make the investment worth it? (years, cost savings, etc)

Consulting Engineer Interview Guide Questions

Background Questions on Consulting Practice

1. What portion of your work is with industrial compressed air?
2. What geographic area does your work on compressed air systems include?
3. What is the smallest compressor size for which you typically conduct any engineering or optimization services, beyond basic system sizing?
4. What size horse power would you consider a "small" compressed air system?
5. At what size (hp) and level of complexity is your type of engineering consulting services most likely no longer a cost effective investment for end users? i.e. For which types and sizes of systems would a prescriptive approach make most sense?
6. How many existing small compressed air installations would you estimate there to be in the region that your work covers? Do you expect this number to increase, decrease, or stay the same over the next 5 years? Explain. (they may not know)
7. How is your work divided, by percentage or number of jobs, amongst these sizes of compressors? (*Fill in **Row 1 in Table 1**, below)*
8. What are the most common applications that you do design work for in each size category? *(Fill in **Column 1 of Table 2**, below)*
9. How is your work divided, roughly, between work on new compressed air systems and work on existing systems?

Efficiency Measure Questions

10. I have a list of several of the most common energy efficiency measures used in compressed air systems. I would like to find out how common these measures are for compressors of various sizes. I have split up compressor sizes into 4 categories and, for each, will name an efficiency measure. Would you please provide your best estimate of what portion of systems, in each size range, use the measures I am about to name? *(Starting with 0-50HP, read each efficiency measure to interviewee and get estimate of percentage of projects in that size range that employ that measure. Repeat for other size ranges of compressors).* How do these system configurations differ between new and retrofit installations? What things are already in place.
11. What percentage of these measures would be effective for small horse power systems? What percentage of the measures is more applicable for larger systems only? For systems with multiple compressors?

12. Which of these measures do you consider the most cost effective for small compressed air systems, both new and as refurbishments to existing systems? Are there other measures that you would recommend in addition to or instead of these?
13. For these small systems, if you had to pick only one or two efficiency measures/services that would be most likely to maximize benefit per cost, what would those measures be? *(If the measures suggested are not in Tables 1 and 3, add them under 'Other' and collect cost/savings estimate)*

14. What are the approximate measure costs and annual savings associated with some of the most common energy saving features/components that could be added to a small compressed air system? I understand that there is a lot of variability but if you could provide your best estimate, based on the most typical system parameters, that would be very helpful.*(Read each efficiency measure in* ***Table 3*** *and get an estimated cost/savings, if possible)*
15. When estimating energy savings due to various measures/practices, what tools/key assumptions/software do you most commonly use? Are there global assumptions that could reasonably be applied in, for example, estimating savings for the purpose of setting incentive levels for various measures?
16. What, if anything, do you see as the most significant barrier to improved energy efficiency in compressed air systems, particularly small-scale systems?
17. If a utility were to offer a program to improve efficiency for small compressed air systems, do you have any suggestions as to the most readily implementable and cost effective opportunities?
18. What would be the most helpful thing that an efficiency program could offer to help you sell more engineering/efficiency services to the small compressed air market?
19. What kinds of support services, if any, would you recommend for end-users to ensure that energy efficiency is maintained over the long term?
20. What analysis tools do you use?
21. What compressed air trainings, if any, have you participated in within the last year?
22. If additional trainings were offered, would that be a valuable investment of your time?

Market Overview Questions

23. What portion of each size category would you estimate is made up of the following compressor types? *(Fill in Columns 2-8 of* ***Table 2****, below)*
24. Who, in your opinion, are the major manufacturers of compressors less than 100 HP supplying equipment to the Pacific Northwest? Can you rank them in order of market share?
25. Who, in your opinion, are the **major vendors**/distributors of compressors less than 100 HP supplying equipment to the Pacific Northwest? Can you rank them in order of market share?
26. Based on the conversation we have had today, is there anyone else that you would recommend we speak with to better understand the small scale compressed air marketplace and technology?

Table 1: Percentage of Compressors Employing Various Efficiency Measures, by Compressor Size				
	=<50 HP	51-100 HP	101-200 HP	>200 HP
Approx. percentage of projects/workload in size range (row should sum to 100%)				
System sizing				
VFD installed on compressor motor				
Piping system optimized to minimize pressure drop				
Processes optimized to reduce compressed air use/waste				
Standard motor replaced with high efficiency equivalent				
Audit completed on existing compressed air system				
Existing compressed air system checked for leaks				
Advanced controls installed				
System data monitoring included in installation				
Other efficiency measures **refrigerated cycling dryers** **purge control on desiccant dryers** **Zero loss condensate traps** **Waste heat recovery** **Multiple compressor systems** **Two step systems (baseload constant speed compressor with VFD for variable loads)** **Increased receiver capacity to optimize fixed speed compressor.** **Engineered nozzles** **Pressure/flow controllers**				

Table 2. Compressor Type, by Percent, in Each Size Range – know that most compressors are rotary screw? What portion? What is the second?							
	Most Common Application	Rotary Screw	Other Rotary	Reciprocating 1 stage	Reciprocating 2 stage	Centrifugal	Axial
Less than 50 HP							
51-100 HP							
101-200 HP							
Greater than 200 HP							

Table 3. Estimates of Cost and Savings of Small Compressed Air Systems Measures – depends on s it's Possible to answer for small systems? Would they have a payback acceptable to industry? Ask opin effective Sometimes, never, etc							
	VFDs	Piping System Optimization	Process Optimization	High Efficiency Motors	System Audit/Leak Detection	Sequencing Controls	System Monitoring
Typical Measure Cost							
Typical Annual Energy Savings							