Summary of Results for Six Industrial Market Transformation Projects Funded by the Northwest Energy Efficiency Alliance

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ABSTRACT

This paper describes six industrial projects funded for two to three years by the Northwest Energy Efficiency Alliance (Alliance). It provides specific examples and concludes with a table summarizing the market impact, consumer and program costs, electricity savings, and non-energy benefits of each project. The six projects include: a compressed air system optimization; variable speed magnetic coupling; fan speed reduction in pneumatic transport; evaporator fan variable frequency drive (VFD); silicon crystal growing optimization; and aeration reduction in small to medium wastewater treatment facilities. Application of these technologies will benefit industrial customers anywhere in the world

With start-up capital and marketing assistance from the Alliance, these six projects are saving electric energy and improving industrial productivity in a variety of ways. Monitoring and optimization of compressed air systems reduced rapid pressure drops and prevented shutdown of production equipment. A magnetic adjustable speed coupling reduced vibration and lowered maintenance costs. Using VFDs to reduce evaporator fan airflow in controlled atmosphere fruit storage also reduced product weight loss. Adding thermal insulation and a radiation shield to a silicon crystal grower increased production by 30% and reduced Argon gas consumption by 85%. Optimizing aeration to improve facultative digestion reduced aeration energy, reduced odors, and brought smaller wastewater facilities back into environmental compliance.

New product spin-offs include: low-cost process controls for small wastewater facilities, low energy silicon feedstock, protection of motors from jammed loads, and optimized compressor system operations. However, projects without non-energy benefits (e.g., fan speed reduction) have found limited market acceptance.

Introduction

The Alliance funds market transformation projects that save electricity in the Pacific Northwest (Idaho, Montana, Oregon, and Washington). Since October 1996, the Alliance has administered 32 projects and $111 million of electric utility funding. Table 2 at the end of this paper summarizes data for six industrial projects representing just over $10 million, or 9.2% of the total Alliance funding. The paper begins with project descriptions.

Individual Project Descriptions

The following descriptions for each of the six industrial projects emphasize the results from a few of the demonstration sites, including improvements in productivity and other non-energy benefits.

Compressed Air Systems – Training plus Monitoring and Control

Compressed air systems are dynamic, core services essential to many industrial plants. An Alliance funded motors study (Easton 1999) estimated that 11% of all motor system energy in the Pacific Northwest is used to support compressed air systems and that average energy savings potential is 17.7%. Similar to natural gas, water, and electricity, compressed air is considered by some to be a "fourth utility." Compressed air provides many services such as product cooling, material transport, power tool operation, etc. However, the cost of these services is often not measured even though it can be quite expensive, especially for air powered tools that can have an energy cost seven to ten times higher than using an electric power tool.

The Alliance supports two projects—the Compressed Air Challenge and SAV-AIR. The Compressed Air Challenge provides training for operators. For example a Washington based dimensional lumber company with a 700 horsepower compressed air system had a problem with moisture in their airlines that would freeze and stop operations. Their maintenance engineer attended the Compressed Air Challenge Fundamentals class where he learned more about compressed air systems and met a vendor. Together they replaced the dryers and increased the size of the piping. It stopped the moisture problem and provided in-line air storage capacity. As a result they saved over 2,000,000 kWh/year and took two 150 horsepower compressors off-line and put them into permanent backup, a 43% reduction in compressor capacity.

In a different project, the Alliance formed a partnership with SAV-AIR, a company started in 1997 to develop and implement monitoring and control for distributed compressed air systems. The project began by developing a measurement regime, including local and remote monitoring. The data provided detailed information to support recommendations for system upgrades including capital investments to stabilize system operation and to generate energy savings as high as 50%. Based on responses from compressed air customers, SAV-AIR developed a packaged controls system for use by other engineers.

At one demonstration site, a major Pacific Northwest wood products facility, SAV-AIR worked with a compressed air system using multiple compressors. From earlier audits the facility owners were aware of the need to perform certain measures, such as leak reduction, but they wanted to optimize their system on an ongoing basis.

Before SAV-AIR's compressed air management (Figure 1 below), the facility had

- Measured compressed air energy costs of $175,000 per year,
- Random fluctuating pressure,
- Poor dryer performance, and
- Lack of system information.

After SAV-AIR's system was installed (Figure 2 below), the facility's

- Measured power cost dropped to $120,000, a savings of $55,000 per year,
- Air pressure stabilized at +/- 5 psig,

➢ Air quality became reliable, and
➢ Real time performance data was provided to engineering and management to establish production costs and to backup future capital investments.

While the field tests are too new to provide specific verification, it is estimated that the non-electricity benefit provided by SAV-AIR, especially stabilized air pressure, will reduce down time and increase productivity. SAV-AIR is actively marketing their products and services beyond the Alliance demonstration sites, and while industry is slow to make capital upgrades, orders have begun to come in.

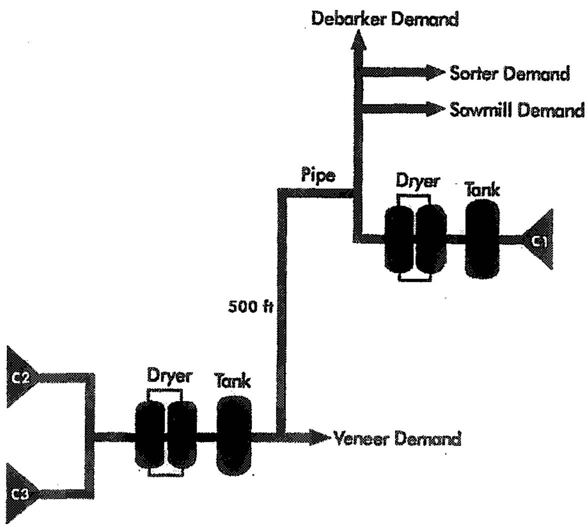

Figure 1. Sawmill Compressed Air

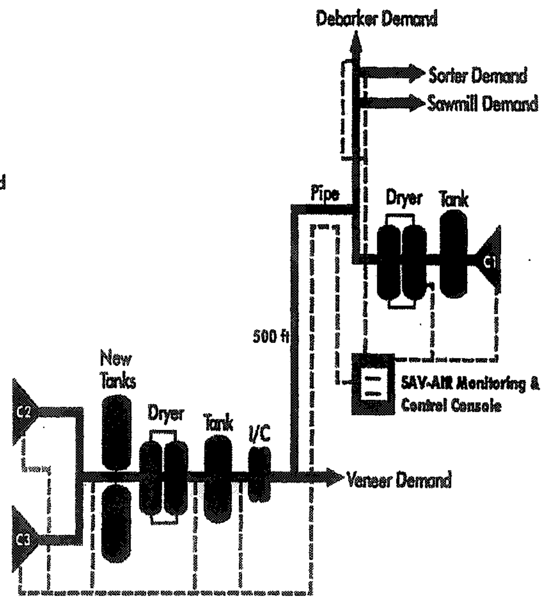

Figure 2. Sav-Air Optimized & Monitored

Magnetic Coupling

The MagnaDrive Coupling increases motor system efficiency. The coupling allows the motor to be physically disconnected from the load. As shown in Figure 3 and Figure 4, the coupling has a copper conductor mounted on the motor shaft assembly that works in concert with a rotor assembly containing rare-earth permanent magnets. The rotor assembly is mounted on the load shaft. By changing the distance between the conductor and the assembly, users can precisely control the torque as required by the load and eliminate the throttling valves or dampers. Laboratory tests indicate that the magnetic coupling achieves on average 65% of the fan savings and 62% of pump savings of a variable frequency drive (Wallace et al. 2000). Field tests and demonstration sites have achieved savings ranging from 25% to 66% in a variety of installations including wastewater, pulp & paper, and HVAC applications. Case studies demonstrated non-energy benefits including reduced down time, increased productivity, significantly less vibration and cavitation, and soft start that eliminates high stress on the motor. (Anderson, Woodard & Wallace 2001)

In an urban wastewater treatment application, the coupling significantly reduced vibration and associated maintenance. The installation was on a 60 HP 1800 RPM system pumping digester bio-solids to belt presses for dewatering. Previous to the coupling installation, the customer relied on two pumps at reduced speeds, VFDs, and bypass valves to control the excessive vibration. The coupling eliminated the bypass and allowed the motor to be downsized to 20 HP 1200 RPM. Facility engineers were impressed by the ability of the coupling to absorb torsional vibration and reduce maintenance requirements. The customer has purchased additional couplings for this and other facilities.

Another case study highlights increased productivity in the bag house of a cement plant, including reduced downtime, elimination of structural damage caused by vibration, and elimination of voltage sags during start up. Originally, the 125 HP 1800 RPM motor used a belt to drive a centrifugal fan, and dampers controlled inlet air volume. This created vibration that caused stress cracks in the system while high starting inertia and heat generated during the start up caused frequent belt failure and lost production. Installation of the coupling as shown in Figure 5 allowed the motor to be aligned with the fan shaft eliminating the belt drive. This resulted in a 25% energy savings, reduction in vibration and noise, and a reduction in both the amount and duration of locked rotor current.

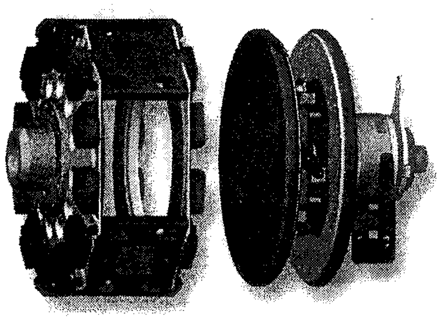

Figure 3. Expanded View of Coupling

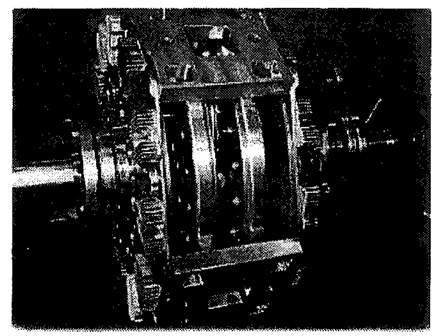

Figure 4. Magnetic Coupling Assembled

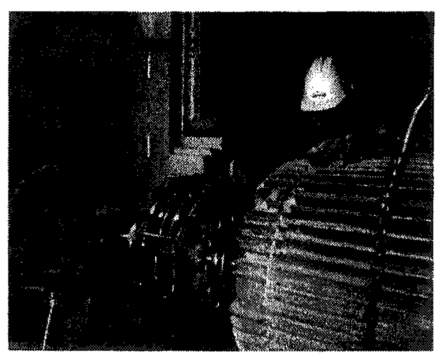

Figure 5. 125 HP Magnet Coupling

These are just two of twenty-seven examples that demonstrate how MagnaDrive's magnetic coupling technology reduced power consumption and increased industrial productivity. Although not an electric saving feature, a spin-off service provided by the magnetic coupling is a shear pin function. A controller can sense when a load is locked or jammed by an obstruction and thus open the gap to prevent motor damage.

Fan Speed Reduction

Just Enough Air is a project contractor's name for their new service to increase energy efficiency of low-pressure pneumatic conveying (LPPC) systems with a fixed reduction in fan speed. The project focuses on wood waste (sawdust, chips, etc.) in the secondary wood processing industry (window fabrication, floorboard production, cabinet manufacturing, etc.). Waste collection can be 10-40% of the electricity requirement. The centrifugal fan of a pneumatic conveying system provides the suction needed to remove and transport the wood waste. The project also recommends other system improvements where appropriate. A small fan speed reduction can significantly reduce operating costs given the cubic relationship of the fan laws. For instance, a 15% speed reduction yields a 38% reduction in annual energy costs. The cost to change sheaves and belts is typically about $1000 per system.

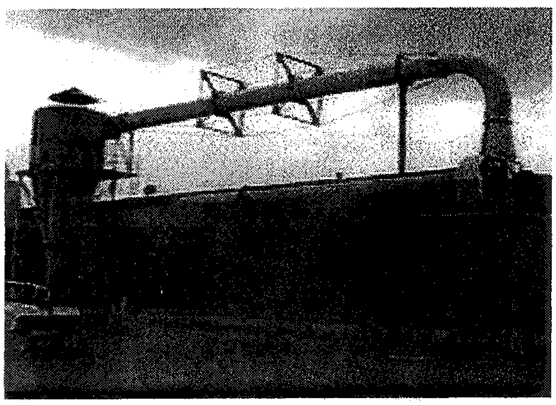

Figure 6. LPPC to Waste Collection

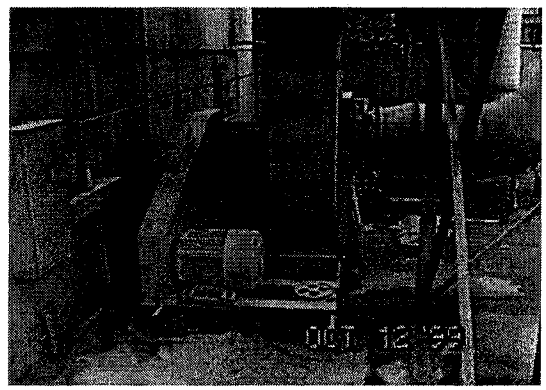

Figure 7. Motor & Fan Belt Assembly

Of the thirty-one facilities audited, twenty-two were good candidates for speed reduction. One facility with a 30 HP fan for cleaning and transfer and a 5 HP bag house fan, saved over 215,000 kWh/year. Airflow volume was reduced by about 3,000 CFM and carry-over from the bag house was reduced. The owner notice there was less mess on the ground.

Woodtape Inc. in Everett, Washington makes thin wood veneer for surfacing doors and furniture. They reduced fan speed by 21% on a 150 HP fan motor and 7.5% on a 60 HP fan motor both used for the LPPC system. Woodtape saved 218,000 kWh/year or 38% of the electricity use for a capital investment of $1,050 plus engineering and test time. This is less than a one-year simple payback. Roger Hunter, Woodtape Process Engineer said, "I recommend the Just Enough Air program highly and would not hesitate to participate further if the opportunity is presented." (Alliance 2000)

Non-electricity benefits of fan speed reduction have not been converted into dollars. Most LLPC wood waste systems are connected to cyclone or bag-houses that tend to blow by wood waste if they receive excessive airflow. Lowering fan speed reduces wood waste contamination of the environment. Reduced exhaust air reduces makeup air heating. In cold climates this can be a significant savings. One benefit appreciated most by facility employees is reduced noise.

Evaporator Fan VFD

The goal of the Evaporator Fan VFD Initiative is to make variable frequency drives an industry standard on evaporator fans in refrigerated warehouses. The target market includes controlled atmosphere fruit storage facilities and conventional cold storage facilities. In the first three years of this project, Cascade Energy Engineering installed VFDs in seventeen controlled atmosphere warehouses and five cold storage facilities.

Fan energy savings from VFDs ranged between 7% and 50%, depending on the extent of fan cycling (turning the fan completely off for a short time) practiced prior to installation of a VFD that slowed the fan speed to a minimum circulation. In the fruit storage facilities, significant non-energy benefits have been documented, primarily in reduced mass loss and increased firmness. For apples, mass and moisture savings ranged from 0.06% to 0.58%. On average this translated to a product savings of about $48.00 per motor horsepower. Cascade Engineering has prepared detailed case study reports and technical papers on energy and non-energy benefits for several annual Washington Tree Fruit Post-harvest conferences. In adaptively managing this project, Alliance and Cascade staff received increased attention from fruit facilities while seeing a smaller level of interest in conventional warehouses. As VFD prices have become more competitive, however, Cascade has seen renewed interest in the conventional warehouse market.

Market interest in VFDs appears to be increasing and several facilities in the Pacific Northwest have installed evaporator fan VFDs without Alliance support or utility incentives. This is an example of the market effects sought by market transformation projects. Early problems with motor failures appear to have been resolved. Cascade has also begun pursuing business opportunities outside the Northwest. Remaining market barriers include the low electricity prices in some Pacific Northwest utility service areas, lack of expertise, lack of sufficient information on the technology and on fruit quality benefits, and the conservative nature of the warehouse industry.

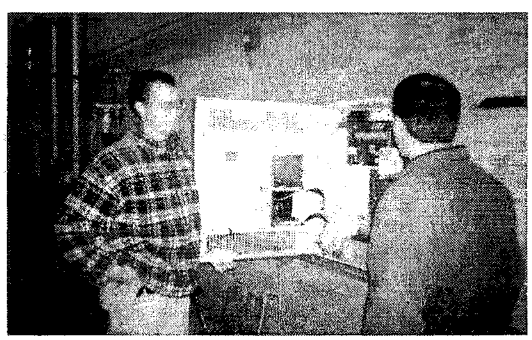

Figure 8. Control Panel for Evaporator VFD

In the remaining months of the project, Cascade Engineering will complete case study reports, develop web-based marketing information, and disseminate information at trade shows and technical forums. They are a strong presence in the Northwest; however, based on the growing interest in this technical approach, it is expected that other engineering firms and refrigeration contractors will enter the market.

Silicon Crystal Growing

This project seeks improved efficiencies in energy-intensive crystal growing furnaces where silicon ingots are produced for photovoltaic and semiconductor applications. A new insulated hot zone as shown in Figure 9 was designed and developed by an engineering team at Siemens Solar Industries (Fickett & Mihalik 2000). The initial focus of the project was to implement the improved furnace at Siemens facilities where silicon ingots are produced for the photovoltaic (solar cell) industry. A condition of the Alliance funding has made it possible to share the design and savings information freely with other firms growing silicon crystals, especially in the semiconductor industry.

Table 1. Silicon Crystal Grower Project Goals and Achievements

	Project Goal	Project Achievement
1	Reduce power consumption by 40% per run (kwh/kg)	Reduced power consumption by **51%** per run (kwh/kg)
2	Reduce Argon consumption by 50% per run (cubic feet/kg)	Reduce Argon consumption by **85%** per run (cubic feet/kg)
3	Increase productivity by 15% (mm/day)	Increased productivity by **30%** (mm/day)
4	Improve or maintain the quality of the ingot produced	Voltage rated current went from 4.0 to 4.2 Amps, a **5%** increase in power.

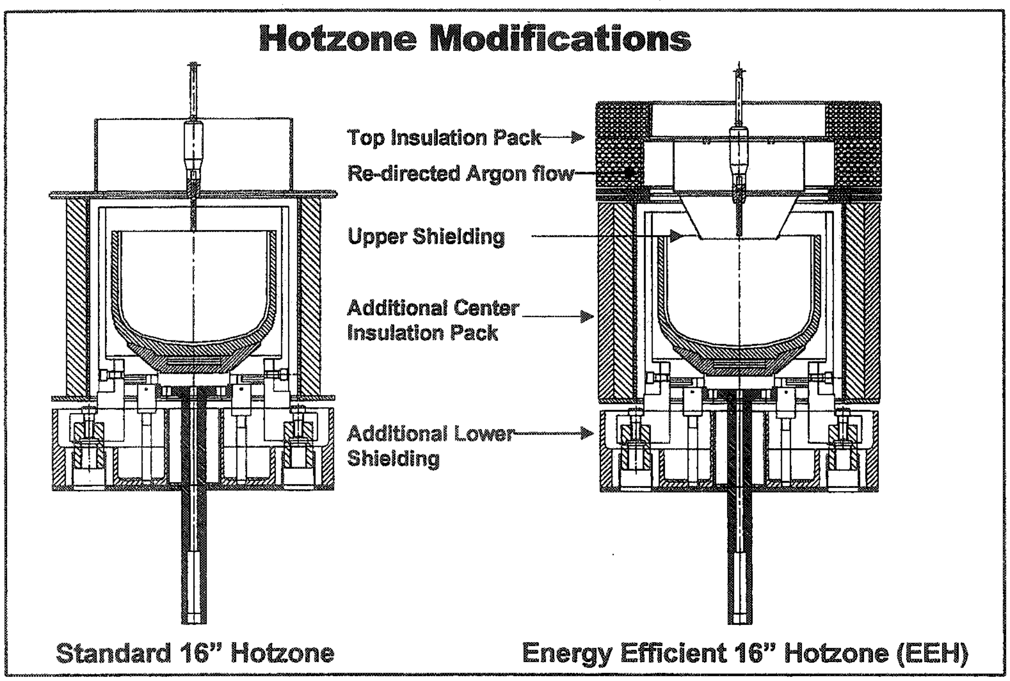

Figure 9. Silicon Grower Before and After Thermal Insulation

The design of a more efficient hot zone met or exceeded the original technical criteria. Table 1 above summarizes the results of the Silicon Crystal Grower efficiency project. Siemens has retrofitted about half of their silicon ingot growers in their current facility, saving 2.1 million kWh/year. They are taking steps to retrofit the rest in 2001.

Business-to-business meetings with others in the industry are helping to facilitate the adoption of the energy saving technology.

The Silicon Crystal project has generated a new spin-off project for the Alliance to test and prove a new low energy process for manufacturing polysilicon, a feed stock for crystal growers at Siemens and other facilities.

Wastewater Treatment

The goal of the BacGen BioWise Initiative is to make optimized aeration for energy savings an industry standard in small to medium-sized wastewater treatment facilities in the Northwest. The approach uses process controls with and without micronutrients (See Figure 11) to improve the facultative zone (See Figure 12) and foster an anaerobic environment in which less aeration and electrical energy is needed. The project is targeted at lagoons and activated sludge facilities. Six municipal facilities in the four Northwest states participated in the project's initial two-year demonstration phase. Results to date show aeration energy savings between 39 and 75 percent. Non-energy benefits include reduced sludge accumulation, reduced need for chemical treatment, reduced odors, and deferral of capital costs for facility expansion. Among the most convincing results to date are improvements at the facility in Dillon, Montana (See Figure 10). With a combination of micronutrients and process controls, BacGen solved environmental compliance problems at this cold-climate site and achieved consistent aeration energy savings up to 75 percent.

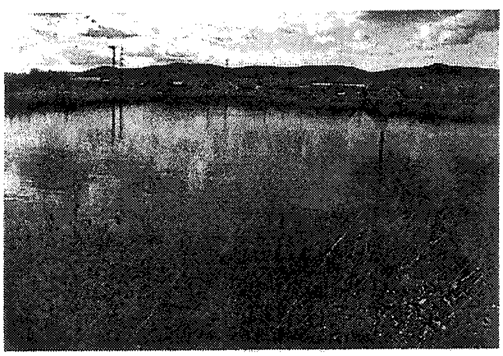

Figure 10. Dillon, Montana Lagoon

Figure 11. Bac-Gen Micronutrient

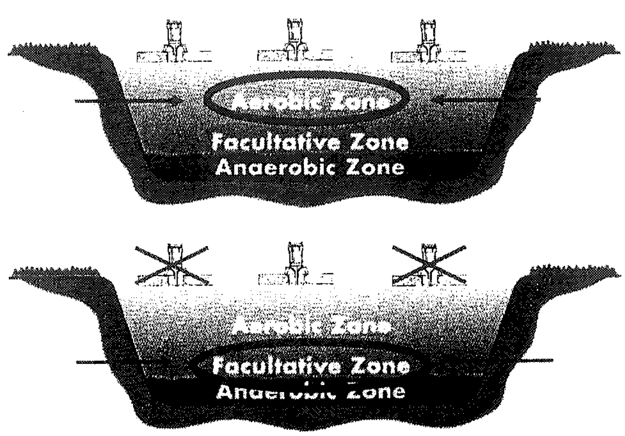

Figure 12. Process moves from Aerobic to Facultative Zone with Micronutrient

Dan Linscott, Dillon Director of Public Utilities, said that BacGen taught their lagoon system operator "more about the operating system and the plant than was ever known before." BacGen significantly improved plant performance by eliminating hydrogen sulfide, ammonia and volatile fatty acid odors. Other non-electric benefits included increased diversity of facultative aerobes, increased carbon oxidation, improved dissolved oxygen utilization, enhanced nitrification, coagulation, flocculation, settleability, and reduced sludge volume (McCourt 2000).

Demonstration site participants show strong acceptance of the BacGen technical approach. Interest appears to be growing in the regional market; however, BacGen will accelerate expansion only after it has accumulated at least one year's performance data and a case study report for each site. In the next phase of the project, BacGen will introduce further technical refinements in up to three additional demonstration sites, develop a business plan to expand its market presence. They plan to use private capital to independently fund installations at up to 24 additional sites in the region.

Adaptive management of this project consisted of a gradual move into process controls as the primary component of the technical approach. Micronutrients were the initial technical tool; but because of their high annual cost, they are now used primarily to mitigate environmental compliance problems when process controls alone are not enough. The project completed fewer demonstration sites than originally anticipated due to lengthy site negotiations and the need for remedial maintenance prior to introduction of the BacGen protocols. The shift from nutrients to controls has improved the cost effectiveness of the project.

Summary Data

Table 2 at the end of this paper presents project contact information, costs, market assumptions, non-electricity benefits and the projected regional electricity savings over the Alliance planning horizon ending in 2010. These factors were used to calculate the overall benefit-to-cost ratio for each project. The table also provides the actual energy savings as of the end of year 2000. The Alliance analyzes projects from a total regional perspective including all costs and all benefits.

Project Costs

There are two primary costs, up-front and annual operations and maintenance. The analysis period runs from the year the project starts to the year 2010. Up-front costs include the Alliance project funding, local utility funding, government funding and finally the largest portion, consumer cost to install the measures. In Table 2 all of the up-front costs are summed together under the label "Total $ by 2010." Total up-front cost ranges from $2.3 million to $34.6 million. The Alliance portion, labeled "Alliance $," is usually a small part of the total dollars ranging from 6.7% to 97.9%. Annual costs (Ann O&M Cost) ranges from zero for three projects to $32,485 for the Wastewater Treatment project. If "Ann. O&M Cost" is less than zero, it becomes a non-energy benefit.

Project Savings

Long-term energy savings range from 68.3 GWh/Yr for Fan Speed Reduction to 350.4 GWh/Yr for Compressed Air System. Electricity savings include market effects after the Alliance support has ended. Table 2 presents the Market size by 2000 and by 2010 which indicates the Alliance estimate of how much the market will grow. The "% of Market" for 2010 represents the long-term project goal. For example, the Magnetic Coupling is a new application for handling variable loads that may not be suitable for VFDs; therefore, we anticipate that this new product will expand the eligible market. Table 1 shows the market size in 2000 to be 718,000 motor horsepower and it grows to 1,484,000 motor horsepower by 2010 (about 12% growth per year). The Alliance project is expected to increase adoption of the magnetic coupling from 8,060 (1.1% of market) in 2000 to 342,000 motor horsepower (30.0% of the market) by 2010.

Non-Electricity Benefits

Non-electricity benefits include productivity improvements, labor savings, and reduced use of consumables such as water, flocculating chemicals, Argon gas, and feedstock materials. They also include energy savings other than electricity, such as natural gas, propane, and steam. Most energy efficiency measures have non-electricity benefits, but only those that have been quantified in terms of dollars are listed in Table 2.

Benefit/Cost Ratio by 2010

The final line item in Table 2 is labeled the "Benefit/cost ratio by 2010." This number accounts for the discounted present value of all regional costs (Alliance cost, local utility administrative costs, government costs, retail consumer costs including operation and maintenance costs, and all private costs not recovered from the profit margin in the consumer cost). The regional benefits include the value of electricity savings based on long-term, time-of-day market electricity price forecast; non-electricity benefits; regional transmission and distribution benefits; and winter peak reduction benefits to distribution upgrades. Benefit/cost ratio must be greater than one for a project to be cost-effective. benefit/cost ratios vary from 1.4 to 11.7 which means these projects return to the region $1.40 to $11.70 for every dollar invested.

Conclusions and Recommendations

In summary all six projects are cost effective even with the low electricity prices of the Pacific Northwest. Market acceptance has been best for projects with identified and documented non-electricity benefits. Achieving consumer acceptance is a long-term process where all benefits must be identified and consumer perception of risk must be eliminated. Alliance market transformation projects seek to make long-term permanent changes to the market structure of the Pacific Northwest. This approach may be slower in achieving immediate electricity savings but it has been demonstrated to achieve low-cost, long-term benefits for consumers and the region.

The authors encourage you to visit the Northwest Energy Efficiency Alliance web-site at www.nwalliance.org to learn more about each of these six projects as well as other Alliance projects.

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Table 2. Data for Six Industrial Market Transformation Projects at the Northwest Energy Efficiency Alliance

Project name	Compressed Air System	Magnetic Coupling	Fan Speed Reduction	Evaporator Fan VFD	Silicon Crystal Growing	Wastewater Treatment
Manufacturer Name	SAV-AIR Century West	MagnaDrive Corp.	Just Enough Air	Cascade Engineers	Siemens Solar	BacGen
Contact Person	David Vanderbeek	Karyl Hansen	John Shin	Marcus Wilcox	Greg Mihalik	Martin Shain
Phone Number	(503) 731-0321	(206) 694-4700	(503) 222-2107	(509) 529-8040	(360) 944-9251	(206) 550-9995
Web-site or e-mail	savair.com	Magnadrive.com	justenoughair.com	mwilcox@bmi.net	siemenssolar.com	BacGenTec1@aol.com
Total $ by 2010	$ 18,624,396	$ 34,637,616	$ 8,120,751	$ 16,174,564	$ 8,852,309	$ 2,266,251
Alliance $	$ 3,054,685	$ 2,317,500	$ 960,420	$ 1,802,314	$ 1,100,524	$ 2,218,500
Alliance $ as % of Total	16.4%	6.7%	11.8%	11.1%	12.4%	97.9%
Est. Savings 2010 (GWh/yr)	350.4	292.6	68.3	121.8	289.1	220.8
Act Savings 2000 (GWh/yr)	1.3	2.19	0.18	7.9	4.6	3.4
Weighted unit	750 HP compressor	Motor Horsepower	Wtd. Facility	Horsepower	Crystal Grower kW	Million gallon/day
Life (years)	10	10	10	10	10	12
Cost	$ 36,200	$ 94.38	$ 17,901	$ 278	$ 50.56	$ 250
Savings (kWh/Yr)	920,000	854	171,637	1,760	2,074	1,155,876
Non-energy benefits	$ -	$ -	$ -	$ 38.00	$ 626.00	$ 120,182
Ann. O&M Cost	$ 14,400	$ -	$ -	$ -	$ 50.56	$ 32,485
Number of measures	1	1	3	2	1	1
Market size by 2000	940	718,000	1,473	81,581	67,525	980
Project Penetration by 2000	6	8,060	11	4,612	5,728	25
% of Market	0.6%	1.1%	0.7%	5.6%	8.5%	2.6%
Market size by 2010	940	1,484,000	1,473	115,536	99,495	1082
Project Penetration 2010	381	342,000	400	69.091	139,257	191
% of Market	40.6%	30.0%	27.2%	59.8%	46.5%	17.7%
Benefit/cost ratio by 2010	1.4	2.1	2.0	2.8	11.7	4.5