Motor Projects in the Pacific Northwest

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ABSTRACT

It is the goal of this paper to provide examples of how industrial motor energy efficiency can be achieved through three generic approaches—load reduction, load control and motor selection. The examples are drawn from programs sponsored by the Northwest Energy Efficiency Alliance. The paper is organized in three parts. Part one—Reduce the Motor Load—is exemplified by three programs in wastewater treatment and crop irrigation. Part two—Control the Motor—is exemplified by four programs: fan speed reduction, compressed air optimization, variable frequency drives on evaporator fans in refrigerated warehouses, and magnetic adjustable speed drives. The third part—Replace the Motor—is illustrated by ten case studies from a motor inventory and premium motor program. The paper tabulates the results of case study projects for each program and provides links to more detailed project information. By the end of 2002 the eight motor programs saved over 80 million kWh per year and by 2010 are projected to save 1,400 million kWh/year. The total regional investment, including all consumer, Alliance, and local utility costs, will be $210 million. Assuming an industrial electric rate of $0.06 per kWh, all projects combined have a simple payback to the region of 2.5 years.

Introduction

Beginning in October 1996 the Northwest Energy Efficiency Alliance (Alliance) began assembling a portfolio of market transformation programs to help catalyze the region into capturing cost effective energy savings. It is the goal of this paper to show that the Alliance's industrial programs have demonstrated how consumers can reduce motor energy use and capture cost effective benefits.

The Alliance has been authorized to invest a total of up to $164 million provided by the Bonneville Power Administration, seven public utilities, and six investor owned electric utilities in Idaho, Montana, Oregon, and Washington. So far the Alliance has initiated about 50 market transformation programs in all customer sectors. This paper focuses on the Alliance's eight industrial sector programs dealing with motors as summarized in Table 1. The Alliance investment is used to help vendors develop their market transformation approaches and to cover part of the cost of a few demonstration projects or case studies at individual facilities. Regional investment is the total dollars invested by all parties including the Alliance, local utilities, local government incentives and the retail cost to the consumer.

Easton Consultants and Xenergy, Inc. concluded that consumers in the Northwest's six primary SIC codes (Food, Lumber, Paper, Chemicals, Petroleum, and Primary Metals) have 230,000 motors that consume about 40,000 million kWh/year (Easton, 1999). To address industrial sector market opportunities, the Alliance has invested just over $17.4 million, or about 11% of its total funding. As of the end of 2002, motor savings have been over 80 million kWh/year and by 2010 motors treated by these market transformation programs are estimated to save about 1,400 million kWh/year or about 3% of motor consumption.

Table 1. Summary of Motor Programs

			Savings (million kWh/year)		
	Alliance Investment	**Regional Investment**	**Actual Cum 2002**	**Projected Cum 2010**	**Benefit/Cost Ratio**
Wastewater Treatment	$3,780,500	$17,331,227	10.3	81.7	7.3
Soil Moisture Meter	$270,000	$2,724,865	4.1	55.3	2.4
Irrigation Scheduling	$2,582,264	$14,130,917	8.8	66.6	1.0
Compressed Air Metering	$3,094,685	$30,319,092	18.4	209.9	1.7
Fan Speed Reduction	$748,420	$9,365,236	1.8	39.6	1.0
Evaporator Fan VFD	$1,862,314	$28,731,488	25.7	165.5	1.7
Magnetic Adjustable Speed Drive	$2,317,500	$36,955,116	6.2	292.4	2.9
Efficient Motor Inventory	$2,769,250	$65,591,874	6.2	508.9	1.4
Totals	$17,424,933	$205,149,815	81.4	1419.8	

Program Descriptions

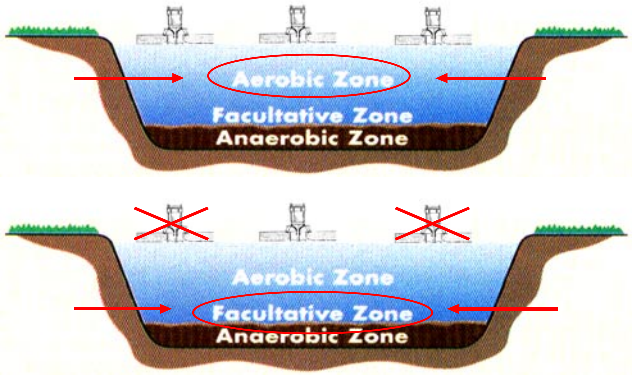
The following program descriptions are presented in three groups that follow the approach of good energy efficiency engineering: seek first to eliminate or reduce the need for motors; second, control the motor to follow the load and reduce energy during idle or low demand period; and finally replace the motor with a properly sized, energy efficient motor. This three-prong approach is important for identifying motor savings opportunities in an individual facility as well as for designing an overall industrial energy efficiency program.

Programs to Eliminate or Reduce Motor Load

There are four Alliance programs that seek to reduce or eliminate the motor load: wastewater treatment process optimization improves the digestion process and reduces the need for aeration pump energy; and three irrigation programs reduce the need for water and therefore the need for pump energy. The Scientific Irrigation Scheduling (SIS) program treated 47,000 acres and showed farmers how to measure soil moisture and how to use weather data to determine precisely how much water was needed for crops. This practice reduced pumping energy and assured that crop yields were maximized. The Alliance has just started two additional irrigation programs with a similar goal. The first is marketing support for an affordable soil moisture meter that encourages farmers to learn and practice scientific irrigation. The Alliance is now considering a new program to demonstrate the benefits of sub-surface drip irrigation.

Wastewater treatment. The goal of the BacGen project is to make optimized aeration for energy savings an industry standard in small- to medium-sized wastewater treatment facilities in the Northwest. Figure 1 shows the bacterial composition of a typical lagoon facility. The approach uses process controls to optimize facultative bacteria that are more efficient and require less aeration, thereby reducing the electrical energy needed for aeration pump motors. The program is targeted at aerated lagoons and activated sludge facilities. Six municipal facilities in the four Northwest states participated in the Alliance program's initial two-year demonstration phase and showed aeration energy savings between 39 and 75 percent. The Bonneville Power Administration, Puget Sound Energy and the Energy Trust of Oregon are now providing direct financial support to bring the technical approach to additional facilities. Non-energy benefits include reduced sludge accumulation, reduced need for chemical treatment, reduced odors, and deferral of capital costs for facility expansion.

Figure 1. Process Controls Move the Process from Aerobic to Facultative



Dan Linscott, Dillon, Montana 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 improved plant performance by 75% and eliminated 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). Table 2 shows measured results at nine municipal and one industrial wastewater treatment facilities in the Northwest. Paybacks are based on electricity savings only, but non-energy benefits like reduced sludge build-up brings some paybacks down to less than a year.

Table 2. Wastewater (BacGen) Case Studies

Site	State	Accounts	Flow MGPD	Savings (kWh/year)	Cost	Payback
A	OR	5,000	0.9	461,620	$54,281	2.4
B	OR	5,000	0.9	368,572	$56,800	3.1
C	WA	35,000	11.4	1,083,170	$94,612	1.7
D	ID	9,000	1.2	202,584	$34,318	3.4
E	MT	5,000	0.5	185,306	$32,630	3.5
F	MT	2,000	0.2	157,104	$27,020	3.4
G	MT	4,000	1.2	282,310	$49,370	3.5
H*	WA	1	8.5	390,098	$38,012	1.9
I	OR	5,000	3.0	829,437	$82,250	2.0
J	OR	5,000	0.9	153,168	$27,612	3.6
Totals		75,001	28.7	4,113,369	$493,000	2.5

* Industrial pulp and paper wastewater treatment

Irrigation programs. Three of the Alliance agricultural programs are intended to reduce the need for irrigation water and therefore reduce energy usage for pumping. Scientific Irrigation Scheduling (SIS) enables irrigators to supply the right amount of moisture to their crops at the right time according to plant growth and weather. In addition to reducing energy costs for pumping water for irrigation, SIS conserves water and reduces fertilizer use and run off. This program provided information and assistance directly to growers representing about 47,000 acres and it expanded the permanent use of scientific irrigation scheduling by Northwest crop growers. When the Alliance program concluded at the end of 2000, a number of agricultural consultants and fieldmen were offering SIS throughout the Northwest as part of their on-farm services and about 38% of the available acreage in the region was using SIS. Estimates based on the Census Bureau's Farm and Ranch Irrigation survey indicated that SIS would be used for about half the available acreage by 2006.

Although direct training was no longer necessary, the Alliance decided to support products and services primarily for low-value crops. One product that helps assure the continued adoption of SIS is the AM-400, a low-cost soil moisture meter and data logger. The easy-to-use device provides irrigators with on-site access to soil moisture data. Typically, this information must be obtained by hiring crop consultants with expensive and difficult soil moisture meters. Consultants are primarily reserved for high-value crops. The low-cost AM-400 Soil Moisture Data Logger allows the farmer to view simple graphs of soil moisture readings from as many as six sensors located in his field up to 1,000 feet away from the meter. At a glance he can determine if he needs to add more or less water. The program has sold about 500 AM-400 meters beyond the sales in past years. Each meter is assumed to serve 80 acres for a total of 40,000 additional acres using better water management.

The Alliance is about to launch a new program to demonstrate the benefits and cost-effectiveness of sub-surface drip irrigation that will further reduce water use by limiting evaporation losses in low-value crops. The three-year program will be applied to six alfalfa fields in the region.

Programs to Control the Motor

Once the load is minimized, the next best strategy for reducing motor energy is to control the motor to properly match or follow the load and thereby reduce overall energy use. Four Alliance programs do this: Compressed Air Optimization, Fan Speed Reduction, Evaporator Fan Variable Frequency Drives (VFD), and Magnetic Adjustable Speed Drive.

Compressed air optimization. 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 on average about 18% of that could be saved. 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 programs—the Compressed Air Challenge (CAC) and SAV-AIR. The CAC provides training for operators. For example, a Washington-based dimensional lumber company with a 700 HP compressed air system had a problem with moisture in their air lines that would freeze and stop operations. Their maintenance engineer attended the CAC 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 to stop the moisture problem and provide in-line air storage capacity. As a result they saved over 2,000,000 kWh/year and they put two 150 HP compressors into permanent backup, a 43% reduction in compressor capacity.

The Alliance also formed a partnership with SAV-AIR, a company started in 1997 to develop and implement monitoring and control for distributed compressed air systems. The program 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.

A major Northwest wood products facility manager attended the CAC training and conducted audits, so he knew that his facility needed leak reduction. He decided to seek out SAV-AIR to do a more thorough audit and to optimize his system. Figure 2 below shows the multi-compressor system that cost $175,000 per year to operate, and sometimes experienced random pressure fluctuations that stopped production. The system had poor dryer performance and the facility manager had no system information. After SAV-AIR's system was installed as in Figure 3 below, the facility's power cost dropped to $120,000 saving $55,000 per year, and air pressure stabilized to a reliable +/- 5 psig. With the on-going system information, the facility manage has better production cost data and he can pursue additional savings opportunities.

Table 3 below lists additional case studies with simple paybacks of less than a year to six years for projects with major capital upgrades. Savings range from 17 to 60%.

Figure 2. Sawmill Compressed Air

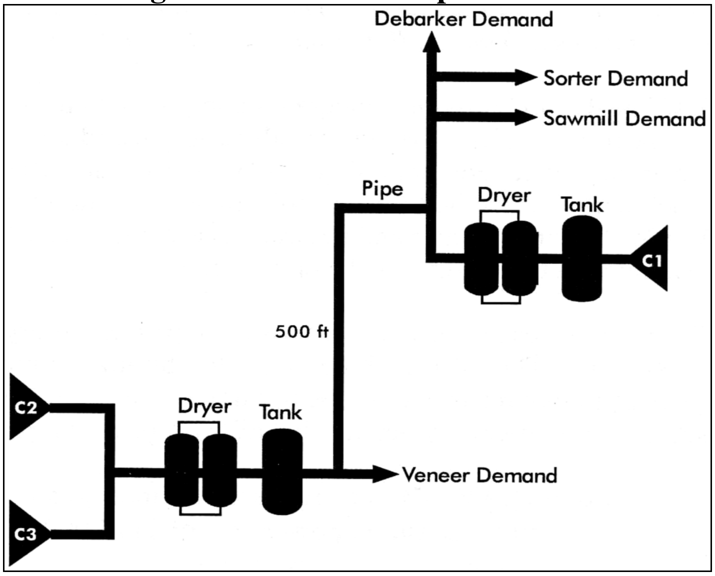


Figure 3. Sav-Air Optimized & Monitored

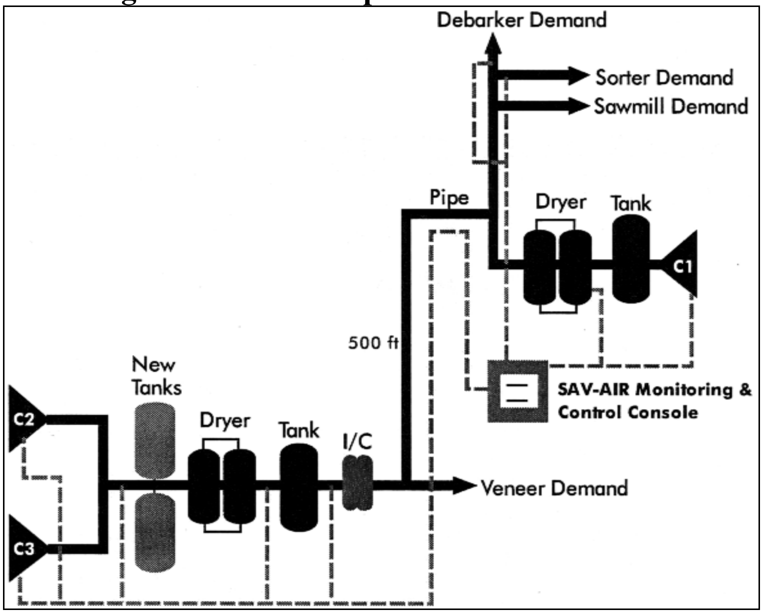


Table 3. Compressed Air (SAV-AIR) Case Studies

	Annual Energy (kWh/year)			Project Measures Cost & Payback		
	Before	After	Savings	Measures	Cost	Years
Mineral Processing	$175,000	$77,000	$98,000 (56%)	Controls, 3 compressors, new dryer, receiver & building piping	$395,000	4.0
Wood Products	$175,000	$120,000	$55,000 (31%)	Controls, receiver, dryer repair	$110,000	2.0
Metals Casting	$193,000	$118,000	$75,000 (39%)	Controls	$30,000	0.4
Cable Manufacturer	$53,300	$28,200	$25,100 (47%)	Controls, one compressor	$52,000	2.1
Plywood Plant	$120,000	$99,600	$20,400 (17%)	Controls, valve upgrades	$123,000	6.0
Particle Board Plant	$85,000 Estimated	$64,000	$21,000 (25%)	Controls and system design for new plant	$21,000	1.0
Wood Products	$118,000	$76,700	$41,300 (35%)	Controls, piping, receiver	$175,000	4.2
Transportation Manufacturer	$82,500	$55,000	$27,500 (33%) Estimated	Controls, piping, receiver	$101,000	3.7
Wood Products	$74,500	$30,000	$44,500 (60%)	Controls, dryer, piping, receiver	$138,000	3.1
Wood Products	$104,400	$68,200	$36,200 (35%)	Controls, receiver	$122,500	3.4
Plywood Plant	$120,700	$86,400	$34,300 (28%)	Controls, piping, dryer, receiver, move compressor	$103,000	3.0
Wood Products	$143,500	$114,200	$29,300 (20%)	Controls, receiver, two compressors	$80,000	2.7

Fan speed reduction. Just Enough Air is a program 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 program 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% to 40% of a facilities electricity requirement. The centrifugal fan of a pneumatic conveying system provides the suction needed to remove and transport the wood waste. The program 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.

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. Sawdust escaping from the bag house was reduced and the owner noticed 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 of which are 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 and requires less make-up air heating. In cold climates this can be a significant savings. Most facility employees appreciated the reduced noise. Table 4 lists savings for 10 regional installations that have a detailed case study posted on the Alliance web-site.

Table 4. Fan Speed Reduction Case Studies

			Savings			Payback
Site	**State**	**Project Cost**	**Percent**	**KWh/year**	**Dollars**	**Years**
A	OR	$15,000	26%	1,798,400	$72,000	0.2
B	WA	$18,537	38%	312,460	$21,505	0.9
C	OR	$119,500	44%	403,645	$20,141	5.9
D	ID	$3,420	23%	26,400	$1,435	2.4
E	WA	$2,340	36%	243,000	$16,225	0.1
F	WA	$4,607	38%	217,525	$9,133	0.5
G	OR	$48,820	18%	188,099	$6,383	7.6
H	OR	$136,188	34%	218,250	$7,523	18.1
I	MT	$3,000	50%	27,900	$2,395	1.3
J	OR	$136,188	46%	129,000	$8,095	16.8
Totals		$487,600		3,564,679	$164,835	3.0

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 (CA) fruit storage facilities and conventional cold storage facilities. This Alliance program supported field demonstrations of VFDs in 18 CA warehouses and six cold storage facilities.

Table 5 presents energy savings for 22 of the demonstration sites. VFDs reduced energy use by between 25% and 86%, depending on the extent of fan cycling (turning the fan completely off for a short time) practiced prior to VFD installation. In the fruit storage facilities, significant non-energy benefits have been documented, primarily in reduced mass loss and increased firmness. Mass savings ranged from 0.19% to 0.58%. Payback in Table 5 include both energy and non-energy benefits. For apples the non-energy benefits were about $48.00 per motor horsepower. Site A Table 5 has a negative payback even though it reduced energy use by over 66%. This was caused by a loss of product mass and it demonstrates why non-energy benefits are so important. In addition to tree fruit, VFDs have most recently been applied to potato storage facilities.

Evaluations determined that early problems with motor failures were resolved and the market is accepting the recommendation of VFDs from refrigeration and electrical contractors throughout the Northwest; and they are being installed without utility incentives, a major indicator of market transformation.

Table 5. Evaporator Fan VFD Case Studies

	Trial Year	Project Cost; Payback (Years)	Rooms with VFD	Mass Savings	Fan Energy Savings (kWh/year);Percent
A	1998	$2,600 ; -0.8	2 of 60 rooms	-1.33%	23,862; 66.4%
B	1998	$2,900; 2.9	1 of 57 rooms	0.27%	10,502; 57.4%
C	1998	$2,000; 1.1	1 of 31 rooms	0.32%	29,647; 76.7%
D	1998	$3,200; 1.1	1 of 46 rooms	0.23%	50,919; 72.3%
E	1999	N/A	2 of 6 rooms	N/A	No formal test
F	1998	$2,600; 1.3	1 of 49 rooms	0.58%	21,422; 40.8%
G	1999	$3,500; 3.6	6 of 52 rooms	0.26%	15,016; 65.1%
H	1999	$5,201; 3.1	1 of 64 rooms	0.19%	38,152; 60.7%
I	1998	$2,600; 1.7	1 of 40 rooms	0.35%	16,424; 53.7%
J	1998	$2,600; 2.0	1 of 20 rooms	0.29%	4,857; 24.5%
K	1999	$3,750; 3.5	9 of 89 rooms	0.30%	25,544; 56.9%
L	1999	$2.600; 2.4	2 of 150 rooms	0.21%	25.564; 71.0%
M	1998	$2,600; 2.4	2 of 150 rooms	0.20%	26,710; 72.0%
N	1998	$2,600; 1.1	3 of 100 rooms	0.44%	59,193; 67.0%
O	1998	$2,600; 1.1	1 of 37 rooms	0.25%	46,564; 78.4%
P	1999	N/A	1 of 12 rooms	N/A	Fruit test only
Q	1999	$32,142; 2.3	10% 300,000	N/A	252,804; 61.7%
R	2000	$27,998; 8.0	100% 25,000	N/A	92,906; 77.4%
S	2001	$76,570; 3.9	50% 1,000,000	N/A	452,387; 72.0%
T	2000	$85,813; 3.8	95% 150,000	N/A	518,202; 63.1%
U	2000	$41,823; 1.4	100% 200,000	N/A	545,151; 86.0%
V	2000	$55,934; 4.4	33% 90,000	N/A	327,815; 73.1%

Magnetic adjustable speed drive. MagnaDrive's magnetic coupling increases motor system efficiency and allows the motor to be physically isolated from the load. The coupling has a copper conductor mounted on the motor shaft that works in concert with a rotor containing rare-earth permanent magnets on the load shaft. By changing the gap distance between the conductor and the magnets, operators can precisely control the speed of the load thus eliminate throttling valves and dampers. Laboratory tests indicate that the magnetic coupling achieves on average 65% of the fan savings and 62% of pump savings of a VFD. Field tests and demonstration sites have achieved energy savings ranging from 25% to 66% in a variety of installations including wastewater, pulp & paper, and HVAC applications. Case studies also demonstrated non-energy benefits including reduced down time, increased productivity, less motor vibration and pump cavitation. MagnaDrive's soft start reduces motor stress cause by high starting torque. (Anderson, Woodard & Wallace 2001)

In an urban wastewater treatment application, the coupling significantly reduced vibration and associated maintenance on a 60 HP, 1800 RPM motor that pumped digester bio-solids to belt presses for dewatering. The old system used VFDs to run two pumps at reduced speed and a bypass to control excessive vibration. The coupling eliminated the bypass and allowed the motor to be downsized to 20 HP, 1200 RPM motor. Facility engineers were impressed by the ability of the coupling to absorb torsional vibration and reduce maintenance. The customer purchased additional couplings.

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 design created vibration that caused stress cracks in the ducting. High starting inertia and heat generated during start up caused frequent belt failure and lost production. Installation of the coupling allowed the motor to be aligned with the fan shaft eliminating the belt drive. The installation resulted in a 25% energy savings, reduction in vibration and noise, and a reduction in both the magnitude and duration of locked rotor current. Table 6 summarizes the savings for six demonstration sites. The Pennsylvania case study was not financed by the Alliance but is included in Table 6 to show how MagnaDrive's soft loading allowed the designer to specify a smaller motor and still meet the starting load. Even though MagnaDrive saves less energy than a VFD, non-energy benefits often drive customer decisions.

Figure 4. 125 HP Magnet Coupling

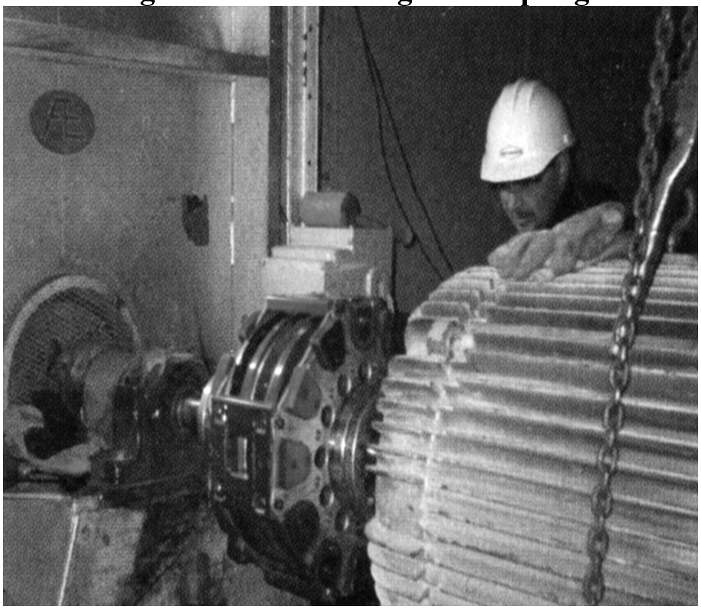


Table 6. MagnaDrive Case Studies

Participant	State	Motor Size (hp)	% Savings (kWh/year)	Non-energy Benefits
55-story Office	WA	One 125-hp chilled water & one 75-hp condenser water pump	31% chilled, 66% condenser	Eliminate vibration, lower O&M cost
Wastewater treatment facility	OR	One 60-hp digester pump, (reduced to 20-hp motor)	50% pump energy	Replaced failed VFD, downsized the motor to 20 hp, eliminated vibration
Pulp and Paper 1	WA	One 250-hp process water pump	62% of pump; (633,000)	Eliminate vibration, lower O&M cost
Pulp and Paper 1	WA	Two 100-hp wastewater pumps	56% of pump; (700,000)	Eliminated water hammer saved $15,000 in O&M cost
Cement & Lime	OR	One 125-hp bag-house fan	25% of fan ; (155,000)	Eliminated air turbulence & stress cracks, saved $10,000 in O&M
Coal Mine	PA	One 600-hp conveyor motor	None (smaller motor upgrade)	Replaced fluid coupling, cut vibration and voltage spikes. Low first cost

Programs to Replace the Motor

Efficient motor management. Over 100,000 motors fail each year in the Northwest, but very few were replaced with high efficiency motors or were reconditioned to specifications that ensure longer life and energy efficiency. Electric Motor Management (EMM), called DrivePower, helps industrial facilities to plan for motor failure, to replace existing motors with high efficiency premium motors, and to require rewinds to meet more efficient standards. The program hopes to increase the overall efficiency of in-service electric motors in the region by focusing on motor-management benefits of lowered operating costs, greater reliability, and reduced production downtime. The program commissioned highly experienced field consultants to personally tailor motor-effectiveness information and services to client-company needs. The program developed motor analysis tools, repair guides and specifications, and sample procurement policies. The consultants provide assistance to industrial facilities, motor dealers, repair shops, industry associations and local electric utilities.

The region's potential energy savings from premium efficiency motors and efficient rewind is estimated at 3,400 million kWh/year. This Alliance program proposes to capture 500 million kWh/year by 2010. Table 7 lists ten regional facilities that prepared motor inventories to help them make better repair or replace decisions, but only a few were able to document energy savings. The Alliance is continuing to work with industrial facilities by providing motor experts to help document motor installations and to improve in-field motor testing. The Alliance is reviewing its overall industrial strategy; motors are a key factor as they represent 70% of the region's industrial electricity use.

Table 7. Motor Inventory Case Studies

Name	State	Number of Motors
Cement	OR	600
Lumber	OR	450
Wastewater	WA	95
Wastewater	WA	80
Millwork	ID	500
Lumber	OR	175
Aircraft	WA	500
Timber	MT	750
Woodworking	ID	90
Hardwood Finishing	WA	400

Conclusions and Recommendations

In summary, the eight Alliance programs and the detailed project case studies highlighted in this paper prove that industrial facilities can save motor energy and achieve cost effective benefits. Savings can come from reducing the load, controlling the motor, and installing energy efficient motors. In many cases these three approaches can be combined to maximize facility benefits.

The authors encourage you to visit the Northwest Energy Efficiency Alliance website at www.nwalliance.org for details on the programs and project case studies.

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