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Energy Efficient Conveyor Systems

Best Practices for Improving Energy Efficiency on Packaging Conveyor Lines

Compare purchase cost to energy usage on electric motors, drives, components and controls.

According to the U.S. Dept. of Energy, industry accounts for over ⅓ of the country's annual energy bill. Electric motors, steam systems, cooling systems and process heating equipment consume the bulk of the energy. Improvement in these areas will yield the most dramatic energy cost savings for the manufacturer.

When evaluating conveyor equipment for your packaging line, it is important that you consider the annual cost of energy to operate the entire system. While labor and materials represent main line items on the manufacturer's bill of material, energy costs are typically not represented. Electricity cost also goes into the cost of the finished goods, yet equipment is usually purchased on a lowest-first cost basis without regard to cost of operation.

When it comes to energy management specifically for the conveyor line, there are two areas to capitalize on energy savings. The first and most direct energy savings opportunity is through energy efficient motor and drive selection. Beyond component selection, the second opportunity is to utilize an energy monitoring and optimization controls plan. The following are practical and cost saving opportunities to improve efficiency on conveyor lines that also can result in a substantial return on investment.

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Motor and Drive Selection

On a new conveyor line, component selection is important for maximizing energy efficiency. The proper selection of motors and reducers offer the most significant difference in energy savings.

Proper Motor Use

The first goal in specifying motors for your conveyor system is to select the right horsepower for the application. The motors should run at or near full load at all times. Typically, the highest efficiency is reached when the motor is operating at 85-95% of full load.

Energy losses are particularly noticeable when the motors are oversized for the application. If the extra power is not necessary, then it may be worth changing the motors for smaller ones. Even at a 4% energy cost savings, a properly sized smaller motor can often pay for itself within a short period of time --considering the cost to operate a motor is many times the cost to purchase one.

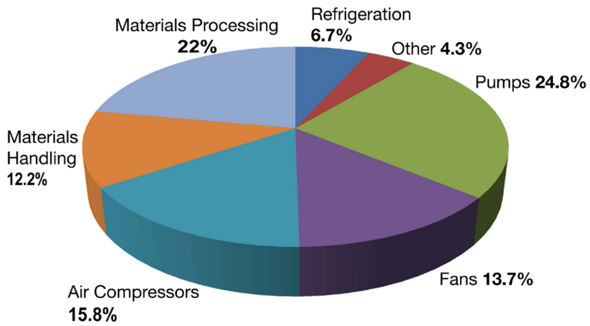
Motors can operate up to their “service factor,” which is typically about 15% above their rated horse power. So if extra power is needed for short periods, such as starting, or shock loading, you may be able to utilize the smaller sized motor on that basis.

If loads vary, use two speed motors or variable frequency drives to enable motors to run near top capacity. In addition to wasted energy, motors that are over sized can cause conveyor component breakage prior to tripping out, before being recognized as a fault, by the motor control. This is often seen in the case of a complete production jam.

Energy Efficient Motors

Premium efficiency motors offer a number of benefits over regular minimum efficient motors. These include lower utility bills, and longer service life. Premium efficient motors typically run much cooler, thereby enhancing the motor longevity.

U.S. Manufacturing Industry
Motor System Energy Usage by Application



This Berkeley Lab study is published by the U.S. Department of Energy.

Motor efficiency is the ratio of mechanical power output to the electrical power input and it is expressed as a percentage. Through innovative design improvements and improvements in manufacturing tolerances, premium energy efficient motors offer increased performance. The higher efficiency motor design factors include:

- Lengthening of the core and using lower dielectric losses through the core and rotor steel
- More copper in the windings to reduce electrical losses
- Larger bearings and more aerodynamic cooling fans
- Smaller rotor to stator air gaps and tighter tolerances

Special acknowledgment goes to Kurz Electric Solutions, Inc. and Baldor Electric Company for their contribution to this article.

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In a standard motor, just the cost of operating it in the first year is more than three to five times the initial purchase price of the motor itself. Reducing operating costs through the purchase of higher efficiency motors can offer a substantial payback. In addition to energy savings, the improved designs and construction of high efficiency motors lead to other benefits:

- Better insulated system, with a higher speed range capability
- Longer bearing life
- Lower heat output generated
- Extended winding life
- Can be de-rated for use on other frequency and voltage supplies
- Generally offers lower failure rates and many include extended warranties
- Provides a motor with construction features that are true inverter duty designs, for variable speed applications.

Energy Efficiency Calculators			
Motor Speed is 1750 RPM	Application Power Requirement (Hp)	Motor Efficiency Standard	Motor Efficiency 86.5%
	2	Premium	
Cost per kWh	Hours of Operation per ***Day***	Days of Operation Per ***Week***	Weeks of Operation per ***Year***
$0.08	24	7	51
Tigear Case Size	Tigear Ratio	Tigear Efficiency 69%	Annual Cost of Operation
23	50		$1,713
Right Angle Quantis (RHB)	Quantis Efficiency not Ration Dependent	Quantis Efficiency 94%	Annual Cost of Operation
			$1,258
In Line Quantis (ILH)	Quantis Gear Stages (2 or 3)	Quantis Efficiency 94%	Annual Cost of Operation
	2		$1,232

Determine Savings and Payback

Efficiency calculators are available from Nercon's motor manufacturer supplier partners. These spreadsheets calculate energy savings based on cost per kilowatt, hours of motor operation, and motor and gear efficiencies.

Also, visit the U.S. Department of Energy website (energy.gov) for free analysis tools, training and publications on best practices for energy management practices.

Energy and Payback Formulas

Annual Energy Savings Formulas

Savings = hp x L x 0.746 x hr x C [100/Estd - 100 - Estd]

Savings is represented by Annual Dollar Amount Saved

hp = Motor rated horsepower
L = Load factor (percentage of full load/100)
hr = Annual operating hours
C = Average energy costs ($/kWh)
Estd = Standard motor efficiency rating, %
Eee = Energy-efficient motor efficiency rating, %
0.746 = Conversion from horsepower to kw units

Simple Payback Formulas

For a new motor purchase:

$$\frac{\text{Price premium - Utility rebate}}{\text{Annual dollar savings}} = \text{Simple payback in years}$$

Simple payback for replacing a motor:

$$\frac{\text{Motor price + Installation charges - Utility rebate}}{\text{Annual dollar savings}} = \text{Simple payback in years}$$

Visit energy.gov for more tools and information.

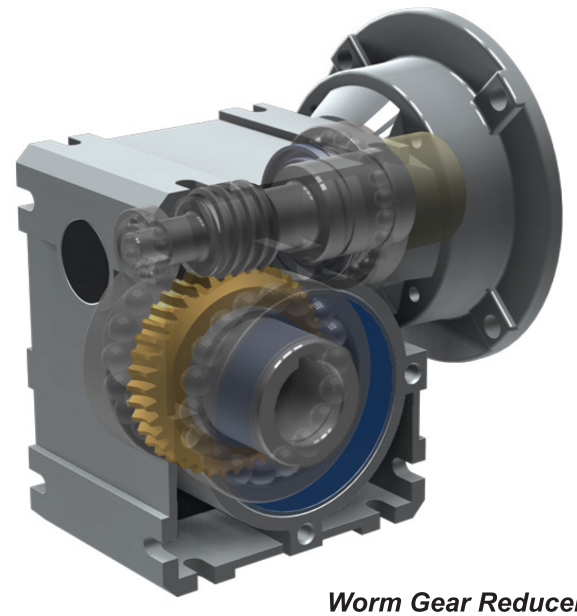
Energy Efficient Gear Reducers

Energy efficiency motors by themselves provide 2% to 8% additional energy efficiency over standard motors. However, it is the gear reducer selection in conjunction with the energy efficient motor that provides the most efficiency for the drive.

The operating efficiencies of worm gear reducers range from 50% to 93%, depending on gear ratio. By comparison, helical gears run at 94% to 98% efficiency per gear stage. When specifying high efficiency motors and drives in packaging lines, it is important to consider the selection of the efficiency of the gear box. Attention is often given to the motors alone, but the energy impact of the whole system is in the selection of both gearing and motors.

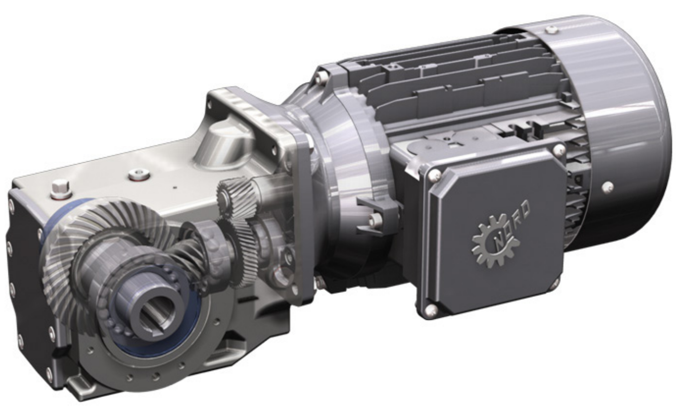
Worm gears are used when large gear reductions are needed in low to moderate horsepower applications. They offer low initial cost, high ratios and high output torque in a small package.

The worm shaft is engineered to easily turn the worm gear, but the output gear cannot back turn the worm shaft. Because of the lead angle on the worm gear, when the output gear tries to back turn, the friction between the gear and the worm holds the input worm in place. This feature is useful for conveyor systems, where the shaft locking feature can act as a brake for the conveyor when the motor is shut off. This is considered to be self locking on any gear ratio of 30:1 or greater. NOTE: This inherent feature of a worm unit, should not be utilized on any application where back pedaling could harm the user of the driven device, such as an elevator. In those cases, the driving motor should also be equipped with a brake and the reducer with a backstop.



Worm Gear Reducer

From an efficiency standpoint, the worm gear is less efficient than a helical bevel gear. For example, worm gearboxes are approximately 64% efficient per horsepower at 30 RPM output (60:1) ratio, which is a very common speed in conveyor systems. The rest of the energy is lost in heat through friction, which causes additional thermal and safety concerns, and is used up in driving the gear reducer output.



Helical Gear Reducer

Payback Analysis with Energy Efficient Upgrade Option

	Helical Gear Energy Efficient Motor	Worm Gear Energy Efficient Motor
Shaft Size	1.437	1.437
Motor Power (HP)	.5	1
Gear Ratio	62.85	60
Output Speed (rpm)	27	30
Gear Efficiency	97%	68%
Motor Efficiency	87.5%	87.5%
Operation Hours/Year	4000	4000
Price of Electricity (¢/kWh)	$.10	$.10
Cost per Year	$175.79	$501.51
Savings per Year	$325.72	
PAYBACK YEARS	.60 (7 months)	

The **helical drive design** is more efficient and capable of handling higher OHLs (Over Hung Loads.) Depending on the application, smaller motors may be possible when used with helical or helical-bevel gear drives. In best practice applications, energy savings in a helical gear reducer will normally pay for the higher initial cost of the reducer. Savings is achieved by using less power which uses less kilowatt hours to handle the load, and because it is a much more efficient unit, the motor can also be downsized and still provide as much or more output torque than the worm reducer equivalent. That way energy consumption is saved by both the motor and reducer.

By comparison, an application requiring a 60:1 ratio (30 RPM Output) will result in an energy savings of $325.00 per year at 10c per kWH (kilowatt hour) when replacing worm gearboxes with helical-bevel type gearing. The payback in years on the higher initial cost helical-bevel unit in energy savings alone is approximately .6 to 1.5 years, using 4,000 operating hours (Two shifts, 50 weeks) per year. After the payback period, the financial result would be an ongoing savings of $325 per year, per unit, not to mention the longer service life, reduced labor replacement cost, and other above mentioned advantages.

Special acknowledgment goes to HuntingtonPT and Nord Drive Systems for their contribution to this article.

Energy Optimization and Controls Planning

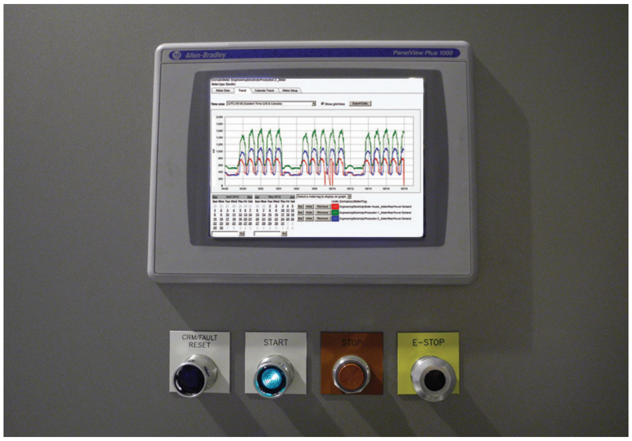
Energy conservation, while prevalent in large manufacturing plants, is becoming more established in medium-sized plants and progressive organizations. With greenhouse gas regulations and cap-and-trade programs being a likely reality in the future, forward thinking companies are examining their energy usage in order to cut costs and remain competitive.

Heating, ventilation, compressed air and cooling systems are the largest users of energy in a manufacturing plant, but there are still other opportunities for conservation in the packaging line itself. The challenge is that the energy consumption on the line is not always visible.

Information monitoring is the key to an effective energy management plan. Cliff Whitehead, Manager of Strategic Applications at Rockwell Automation, says, “Corporate accountants are starting to listen to the energy cost conversation for production lines, so production equipment energy planning is definitely in order.” He offers a four level strategy for production equipment energy management.

1. Monitor and report energy usage at the device and equipment level.
2. Allocate energy cost based on actual usage.
3. Optimize machines and devices (reduce electricity, air, water, etc.)
4. Aggregate the results and review production alternatives to reduce energy usage without compromising product quality and delivery.

As Rockwell Automation’s strategy suggests, best practices for energy management start with monitoring and reporting energy usage on a packaging conveyor line. The simplest method is to include power monitors upstream of electrical loads like motors. Collection of energy data and visualization of the data alone will promote awareness of energy usage. Even though it is manually collected, the data will provide a more accurate picture of energy usage information.

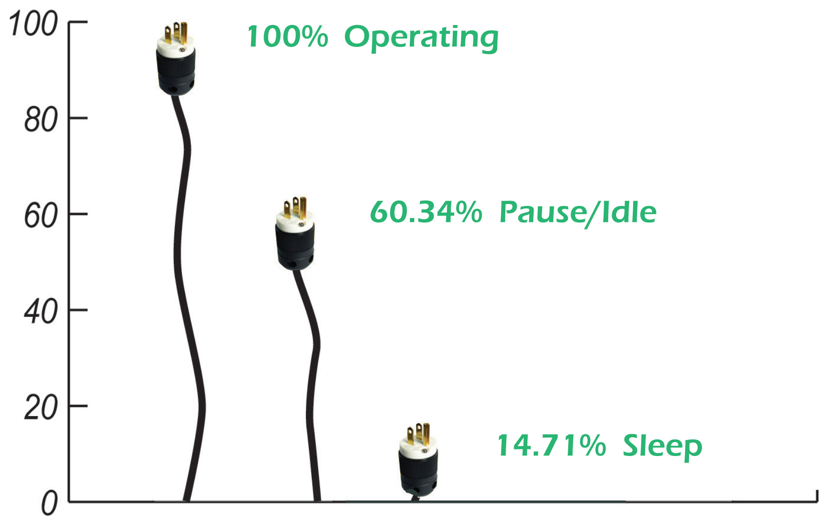


HMI showing an Energy Demand Trend Screen

Simple energy reporting can also be configured on the operator interface. For example, many packaging lines already use the Common Industrial Protocol (CIP) on DeviceNet or EtherNet/IP to monitor and control the machines and conveyors. Recent specification enhancements to the CIP protocol will enable collection of measurement data and direct control of energy loads like variable speed drives with minimal programming and no external meters.

Having the knowledge of where the energy is being consumed is as important as when energy is not necessary. Typically, a conveying system is turned on at the beginning of the day and runs full speed until the end of the day. Many operations, however, do not have a high rate of material flow throughout the production run. The operating mode of a conveyor system is when the material flow on the conveyor dictates that the conveyor is running.

Energy Mode Readings



Taken from a test conveyor loop, this chart is an example of the relative amount of energy savings shown in different states.

The package handling conveyor system can be designed to automatically slow down or stop during periods of lower production, called a pause/idle mode. Control systems can be designed to monitor activity on the system and slow down or speed up to meet throughput demands which only uses the power for the job required.

Systems can also be designed to shut-down to their lowest energy states when not in use, sometimes called a sleep mode. The effects on the duty cycle of electronic devices should be taken into consideration for automatic shut-downs so the life of the device is not compromised due to excessive shutdowns. Best practices for automatic shut-down modes are planned breaks, changeovers and maintenance periods.

Reducing energy can result in more than just saving costs on the electric bill; reducing energy also reduces maintenance on parts and components. In the pause mode example, reducing wear and tear on system components increases the life cycle of the system. Monitoring the torque change in drive and motor packages can indicate when the device is nearing maintenance or replacement.

In summary, the energy conversation is growing. In June 2011, ISO launched the ISO 50001 energy management standard that is estimated to impact 60% of the world's energy use. The standard provides public and private organizations with management strategies to increase energy efficiency, reduce costs and improve energy performance.

Original equipment manufacturers and consumer goods manufacturers, ready or not, will have to employ sustain-ability directives in the near future. Energy isn't an expense to live with; it is a manageable asset and an opportunity to reduce operating costs.

When it comes to energy efficiency on packaging conveyor lines, the conversation is often about the cost to purchase and implement energy efficient components and programs. Motors, for examples, are often purchased with supply chain efficiency as a priority driver and not the most energy efficient choice for the application. Until the energy conversation is driven by the corporative level, the focus is on plant-level energy efficiency actions that provide the fastest return on investment.

Recommended Actions

Recommended Actions for Purchasing Energy Efficient Motor/Reducers

- ✓ Replace failed standard efficiency motors with high efficiency motors.
- ✓ Specify energy efficient motors on packaging machines.
- ✓ Use energy efficient motor packages as part of a preventative maintenance plan.
- ✓ Check with your local utility for rebates or discount programs for upgrades to energy efficient motors.

Recommended Actions for an Energy Optimization and Controls Planning

- ✓ Contract with an industry experience controls solution provider to conduct an energy audit and identify changes that can be made to reduce energy consumption and improve the bottom line.
- ✓ Monitor energy usage. Knowing your energy usage will help drive savings.
- ✓ Check with your power provider for rebates on energy savings solutions.

Energy Products from Rockwell Automation

Rockwell Automation
Machine Builder Partner

Allen-Bradley PowerMonitor W250: Power meter - wireless network translates information to RS EnergyMetrix software for easier energy data collection.

Rockwell Automation Energy Management Accelerator ToolKit: Easy-to-use system design, programming and analysis tools.

Allen-Bradley PowerFlex 755 AC Drive: Supports variable frequency drives, motion drives, I/O, smart actuators and other EtherNet/IP drives on a common network which helps increase design flexibility, improve performance and reduce engineering costs.

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600 S. Commercial St.
Neenah, WI 54956
844-293-2814
www.nerconconveyors.com