Department of Energy

Energy efficiency guidance for the food & beverage sector

Introducing energy saving opportunities for motors and drives

UK Government

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Motors and drives

Electric motors drive the vast majority of processes used in the food and drink industry. However, they are often overlooked and as a result, many sites have relatively inefficient motor operations. Improving the efficiency of a plant's motors can deliver significant energy and cost savings.

According to the World Energy Council, globally, electric motors and electric motor-driven systems are estimated to consume almost 50% of all electricity consumption and account for 70% of electricity consumption in Industry.

In a single year of operation, a motor can cost up to ten times its purchase cost in energy. With this scale of running cost, it is easy to appreciate why paying careful attention to the use and condition of motors is important. The cost savings arising from implementing energy saving initiatives across multiple motors can be significant.

Technology overview:

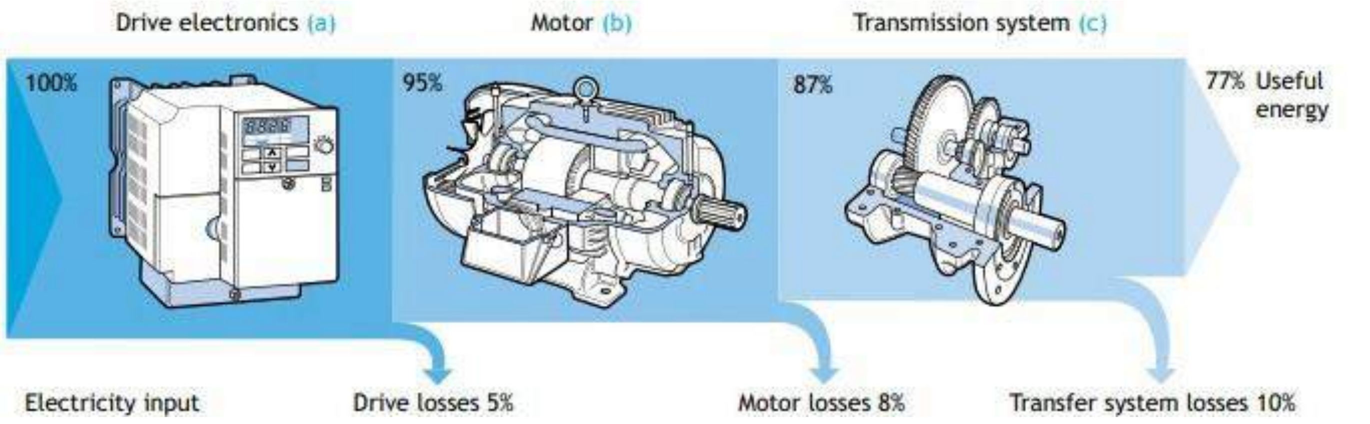
An electric motor is a device for converting electrical energy to rotary kinetic (movement) energy to power a process such as a pump, fan or conveyor. The term drive is used to mean many things in industry, including being used as a generic word for motors, for drivetrains (such as gearboxes or pulley systems), and for controllers.

More accurately, and for the purposes of this guide, 'drive' refers to a motor controller. A variable speed drive (VSD) is an electronic device that controls the electrical supply to a motor, enabling it to run at different speeds.

System losses

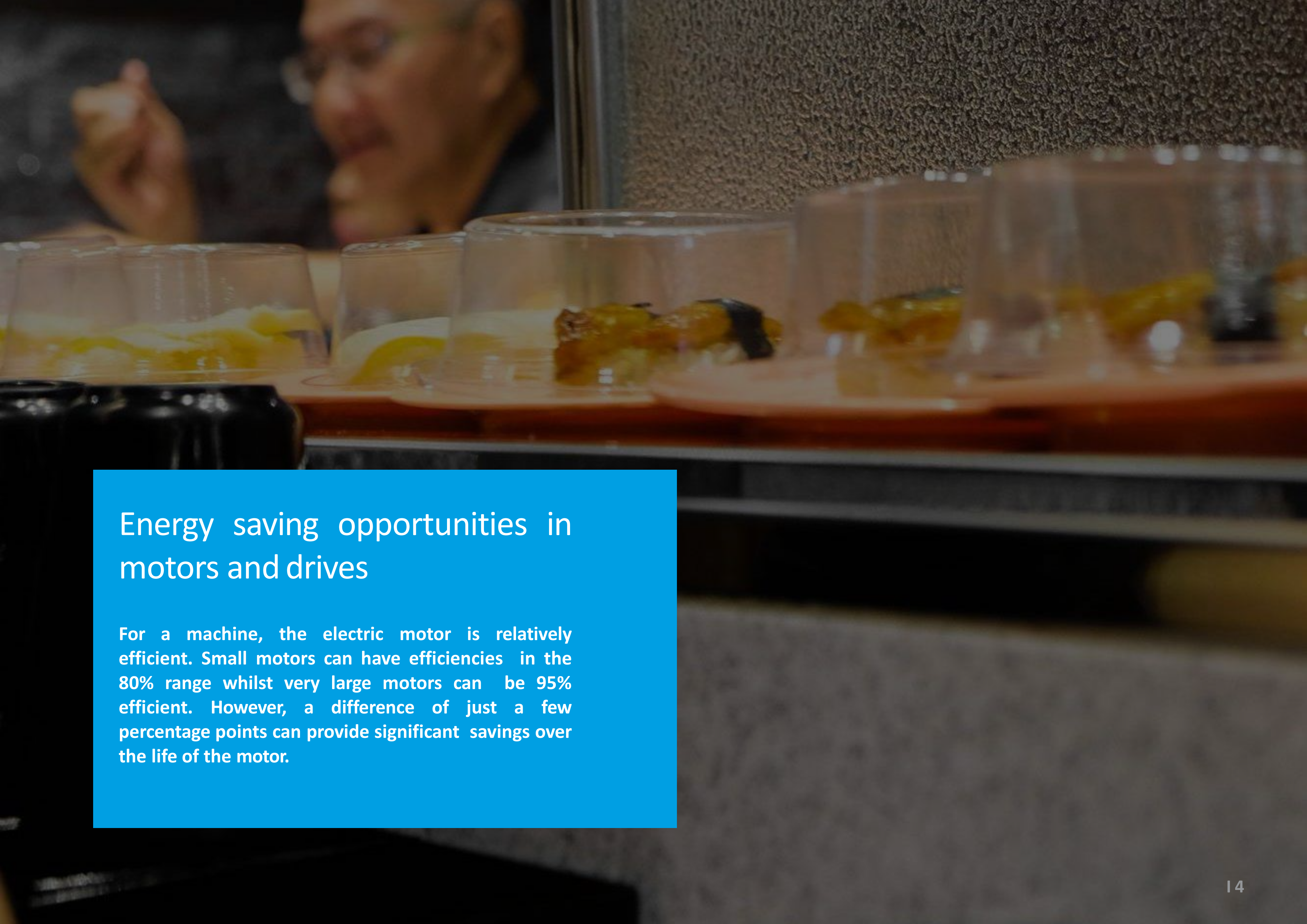
The diagram below shows that only about 77% of the electrical energy input is normally utilised by the load being moved.

The drive unit (a) requires electricity to power the electronics; some of this is wasted as heat in the drive unit (typically 5%). The motor itself has various internal losses (b), and if it is attached to a transmission system (c) of some sort (for example, a gearbox or pulley), then this introduces further losses in the form of friction. So typically, only 75-80% of the energy supplied to the motor system is transmitted to the end-use equipment. The majority of the above losses appear as heat.



Motor efficiency

Modern motors typically operate most efficiently at above 75% loading with a peak at about 90% load. The 'loading' of a motor is the amount of work it does compared with its maximum rated power output. For example, a motor rated at 90kW driving an 81kW load is said to be 90% loaded. Note that the rating plate on a motor states its output power at the shaft, so the actual input energy drawn will be the output power at the shaft plus the power lost due to the motor inefficiency. So, in the example above where the 90kW motor is, say, 95% efficient, then with an 81kW load it will actually draw about 85.3kW from the mains supply.



Energy saving opportunities in motors and drives

For a machine, the electric motor is relatively efficient. Small motors can have efficiencies in the 80% range whilst very large motors can be 95% efficient. However, a difference of just a few percentage points can provide significant savings over the life of the motor.

Switch off motors when they are not required

Motors are so common and often 'hidden' within machinery, they tend to be ignored and left running even when they are doing no useful work.

For the bakery sub-sector, there are a large number of small motors (often less than 0.5kW) installed on the conveyors used to transport dough and bread to and from the oven. The key issue with these motors is ensuring that they are switched off when the conveyors are empty.

It is important to identify all systems that use motors and encourage employees to turn them off when they are not needed. Motivate staff to do so by introducing a traffic light system of labelling controls.

Green	Red
for "safe to shut off when not in use"	*for "do not switch off"*

Alternatively, consider installing automatic sensors that can stop motors and conveyors when no product is being carried. For example, a timer could be used to switch off motor-powered equipment at specified times. Interlocks could also be used so that equipment is switched on only if another device is already running. If this other device is turned off, the interlocked device will also automatically shut down. There are also load-sensing devices available that can sense when there is no load on the motor, allowing it to switch off after a suitable time period, saving energy.

Keep motors and drives in a cool place

A drive can be located either inside an enclosure some distance away from the motor itself, or attached directly to it. Consider this location carefully. As much of the energy loss comes as heat, it is important to keep the drive and motor in a dry, well-ventilated area that is at a suitable temperature to allow for cooling. Larger drives can generate a lot of heat which must be removed or the unit could eventually fail.

Clean components

It is very important to keep motors clean, especially when they are located in dirty environments. Cooling fins on the motor body dissipate heat. If these are covered in dirt, it will reduce the contact the fins have with cooling air. Therefore, a dirty motor will be hotter and hot motors use more energy and are at more risk of failure. To overcome this problem, put a motor-cleaning regime in place.

> *An increase in internal motor temperature of 1 degree Celsius can produce an increase in losses of 0.5% as well as shortening the life of the motor insulation.*

Check that motors are the correct size

Motors are often larger than they need to be.

A smaller motor running at a higher loading will be more efficient than a larger, partially loaded motor and will consume less energy.

An easy way to find out if a motor is correctly sized is to compare the details on the rating plate with the actual rating required by the equipment it is driving. Alternatively, it may be appropriate to monitor the power consumption of the motor using a suitable power meter or logging device.

In many cases, motors are oversized by 20% or more (e.g. an application might require a motor rated at only 7.5kW, but has been supplied with a motor that is 11kW). Consider replacing with smaller, higher efficiency motors where possible. If the motor is very lightly loaded (<40%) and cannot be changed, it may be possible to run the motor continually in a different connection mode that could result in energy savings of between 5 and 10%.

Consider replacing failed motors with higher efficiency motors (HEMs)

HEMs are between 3 and 4% more efficient than other motors due to their improved design and materials. Energy efficiency improvements of up to 5% are possible if failed motors are replaced with higher efficiency models.

Within the dairy sector, motors for driving the fans are set up in the freezing tunnel. The electrical energy supplied to the motors must, therefore, be dissipated by the freezer unit. By opting for high efficiency motors for driving the fans, not only is there a direct saving in electricity, e.g. lower consumption by the fans, but also an indirect saving,
e.g. through the lower cooling load on the refrigeration unit.

It is usually more cost-effective to replace smaller motors (<15kW) than to rewind them. Although the cost of a rewind may be less than buying a new motor, the reduction in energy efficiency will mean that increased running costs will quickly exceed the initial saving.

Motors tend to be 2% to 3% less efficient when rewound.

Generally, the decision on whether to repair or replace motors should be based on motor size — the larger the motor, the more likely for it to be economic to repair rather than replace, depending on the running hours.

Generally speaking, the cost difference between repairing and replacing a smaller motor (typically below 5.5 kW to 11 kW) is so small that replacement should be the automatic choice, irrespective of running hours.

Conversely, for larger motors, repair is usually more economic, depending on the running hours. In between there is a ‘grey area’ which usually requires some thought or calculation before the right choice can be made.

However, some general rules could be applied such as:

- If a motor is below 5.5kW, motor should be replaced automatically rather than repaired.
- If it is a higher efficiency motor (HEM) then it should be repaired.
- If very badly damaged the motor should be replaced.
- If a motor needs to be replaced, but is required urgently, then a special case could be made to justify the action.

Look at the possibility of installing Variable Speed Drives (VSDs)

A VSD is an electronic device that can vary the speed of motor-driven equipment such as a compressor, fan or pump. The VSD converts the incoming electrical supply of fixed frequency into a variable frequency output to control the motor. In applications where the motor has a continuously variable demand, the best solution for reducing the speed of the motor (and hence reducing energy consumption) is to install a VSD.

> *A 20% reduction in motor speed of a VSD will provide energy savings of 50%.*

With cooling processes in baking, the air flow rates are typically controlled by dampers. Here, electricity use could be further reduced by using variable speed drives (VSDs) to control the operation of the fan motor as part of the ventilation systems.

VSDs are usually more expensive than simple motor controls, although have typical payback periods of less than two years.

VSDs may be particularly useful in variable torque load applications such as fans, pumps or centrifugal compressors were output is controlled by throttling or manual damper adjustment.

They can also be useful for constant torque load applications such as screw or reciprocating compressors, conveyors, grinders, mills or mixers that have an output which varies from job to job.

VSDs are commonly used within the food and drink industry, for example, to drive beet slicers to produce sugar for use in chocolate, cake and soft drink processing.
VSDs are also often used to drive extractor fans to control the temperature in ovens, for example for biscuit production. They can be very effective in a variety of processes, particularly those that use pumps and fans.

Ensure motor systems are well maintained

Carrying out regular maintenance can reduce energy consumption by as much as 10%. Maintenance programmes should consist of lubrication schedules, cleaning, belt tensioning and alignment checks. It is also worth considering using predictive maintenance techniques that can indicate in advance when parts will need replacing.

> **Belt tension and condition:** *incorrect tensioning can lead to 5% in losses, whole worn belts can add 4% and should be replaced.*

As part of ongoing motor maintenance policy upgrade to more efficient types.

Element	Efficiency
Flat belts	0.81 - 0.85
V belts	0.88 - 0.93
Toothed belts	0.90 - 0.96

> **Alignment:** *typically a poorly aligned coupling can add up to 8% to the energy required to drive the process.*

Always carry out maintenance in accordance with manufacturer's instructions. Servicing should include:

- A visual check for any gearbox or bearing leaks and damage
- Regular cleaning — ensure motors are kept free of dirt and debris
- A check of the alignment of the motor shaft to the load (see the top tip box below, right)
- A check of the tension and condition of any drive belts
- A check of the motor. Test if it is hot
- An aural check. Listen to it — does it sound the same as normal?
- A suitable lubrication regime (including greasing, oil top-up and oil replacement).

Checklist and tips for efficient operation of motors and drives

This checklist summarises the key criteria and characteristics of energy efficient motors and drives. If you are unable to indicate “YES” to all questions, it is likely that the efficiency of your system could be improved, saving you money and reducing your carbon emissions.

Checklist and tips

Ref	Best practice criteria	Response	Feedback
1	**Are there opportunities to switch of motors when not in use?**	[yes]/[no]	Because motors are often 'hidden' within machinery they tend to be ignored and left running even when they are doing no useful work. Idling/unloaded motors can consume up to 40% of rated power. Efficiency can be improved through simple switch off procedures or auto sensing such at load, pressure or temperature sensing. Simply switching off during breaks can reduce electricity consumption by 15%. Payback is immediate.
2	**Have you checked that motors are correctly sized for the required duty?**	[yes]/[no]	Design margins and process changes can mean that motors are over-rated for the required duty and are therefore inefficient. Savings can be made in a variety of different ways including fitting a smaller motor, fitting a variable frequency drive or fitting an automatic star-delta-star starter that will make between 30-40% savings when the motor loading drops below 40% of the motors rating. Payback < 1 year.
3	**Has a full assessment been potential to utilise speed drives (VSDs)?**	[yes]/[no]	Using a VSD controlled motor enables a better match of the driven machine to the requirements of the process. In applications requiring variable speed and variable torque, such as fans, pumps or compressors, using a VSD can make significant energy and cost savings ensuring the motors speed is nominal for the variable process load. A 20% reduction in motor speed of a variable speed drive will provide energy savings of 50% with project paybacks often < 2 years.
4	**Do your VSDs use real time feedback control to quickly adjust to variable process requirements?**	[yes]/[no]	Where a process load is very changeable dynamic feedback control will adjust the VSD accordingly so matching the process requirement. Using dynamic feedback control increases the possible uses for VSDs and maximises the saving potential. Projects utilising VSDs with dynamic feedback control have paybacks of 1-3 years.
5	**Have you investigated the option to upgrade the air handling units with Electronically Commutated (EC) Plug Fans?**	[yes]/[no]	Replacing existing AC motors and fan configurations in air handling units with variable speed EC plug fans is a very cost effective way to reduce system energy consumption by up to 75% for a project payback of 3.5 years.
6	**Do you replace motors with higher efficiency versions as standard?**	[yes]/[no]	Replacing motors with higher efficiency versions (as specified in IEC60034-30) will save between 2 – 5% of motor running costs. While there is an associated cost premium with choosing a higher efficiency, this will be more than offset by the lifetime savings in running costs over the life time of the motor. Replacing a failed IE2 motor with an IE4 will payback < 1.5 years.
7	**Do you rewind motors rather than replace them?**	[yes]/[no]	Best practice would be to rewind a motor no more than 3 times before replacing due to decreasing efficiency of the windings (2-3% each time). Replacing a rewound IE1 motor with a new IE3 will reduce the annual electricity consumption by <12%. Payback would be < 1 year in many cases.
8	**Do you use a motors and drives maintenance checklist?**	[yes]/[no]	Incorrect installation, commissioning or maintenance means that the factors affecting the efficiency of motors may not be optimised. For example, poor alignment of pulleys, belt slippage, poor belt tension and worn belts are all easily and cheaply rectified through regular maintenance checks. Such checks will provide savings of 9% with < 1 year payback