WHITE PAPER

Achieving the Paris Agreement

The vital role of high-efficiency motors and drives in reducing energy consumption

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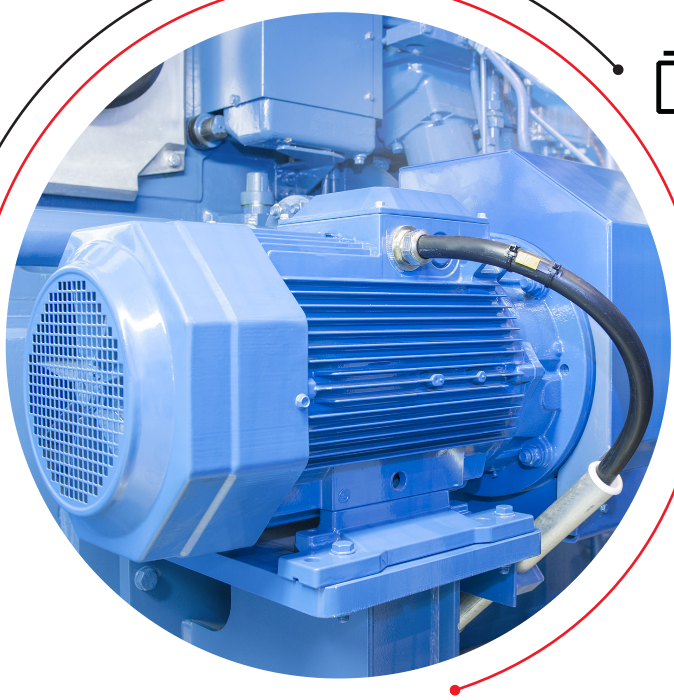
It is estimated that by 2050, the global population will rise to 9.7 billion, from 7.7 billion in 2019.[1] The global economy is expected to more than double over the same period.[2] Urbanization, automation, and the rise of living standards will increase the demand for energy globally. More than half of the world's population now lives in cities and towns, and the United Nations projects that the global urban population will increase to around 68% by 2050.[3] If we continue with business as usual, this scale of expansion will accelerate climate change, and degrade the quality of air and water upon which all living organisms depend. To protect the environment without tempering economic growth, we need to redouble our commitment to reducing the consumption of energy and natural resources.

In keeping with global trends, the demand for electric motion, i.e., drive systems powered by electric motors, is expected to grow significantly. According to the IEA, industry accounts for 37% of global energy use and 24% of global CO_2 emissions,[4] and buildings account for around 30% of energy consumption and 28% of CO_2 emissions.[5] A large proportion of this activity is associated with electric motors. It is estimated that roughly 70% of electricity consumed by industry is used by electric motor systems.[6] In commercial buildings, 38% of electric energy consumption is for motors.[7]



38%

of electric energy use is for motors in commercial buildings.

70%

of electricity consumed by industry is used in electric motor systems.

Electric motors have been in use for 150 years, and they have steadily improved over time. Yet for the past decade, they have undergone a period of exceptionally rapid technological advancement. The latest wave of improvements has opened the door to a significant reduction of the carbon footprint of industrial and commercial electric motors in the immediate future. An expanding range of highly energy-efficient electric motors (rated IE3 or higher) and the variable-speed drives (aka "frequency converters" or "AC drives") that can be used to run them are now available on the market.

These technologies hold the key to enabling many of the signatory countries of the Paris Agreement to meet their carbon reduction targets over the course of the next 10 years. The scope of their impact is potentially enormous.

But to realize the full benefits of high-efficiency motors and drives, all stakeholders have critical roles:

- Public decision-makers and government regulators will need to incentivize their rapid adoption.
- Businesses, cities, and countries need to be aware of both the cost savings and environmental advantages and be willing to make the investment.
- Manufacturers like ABB will need to provide the necessary technologies and continue to drive innovation that improves energy efficiency.
- Investors need to reallocate capital towards companies better prepared to address the climate risk.
- Public education programs will be required to explain and promote the value of these upgrades.

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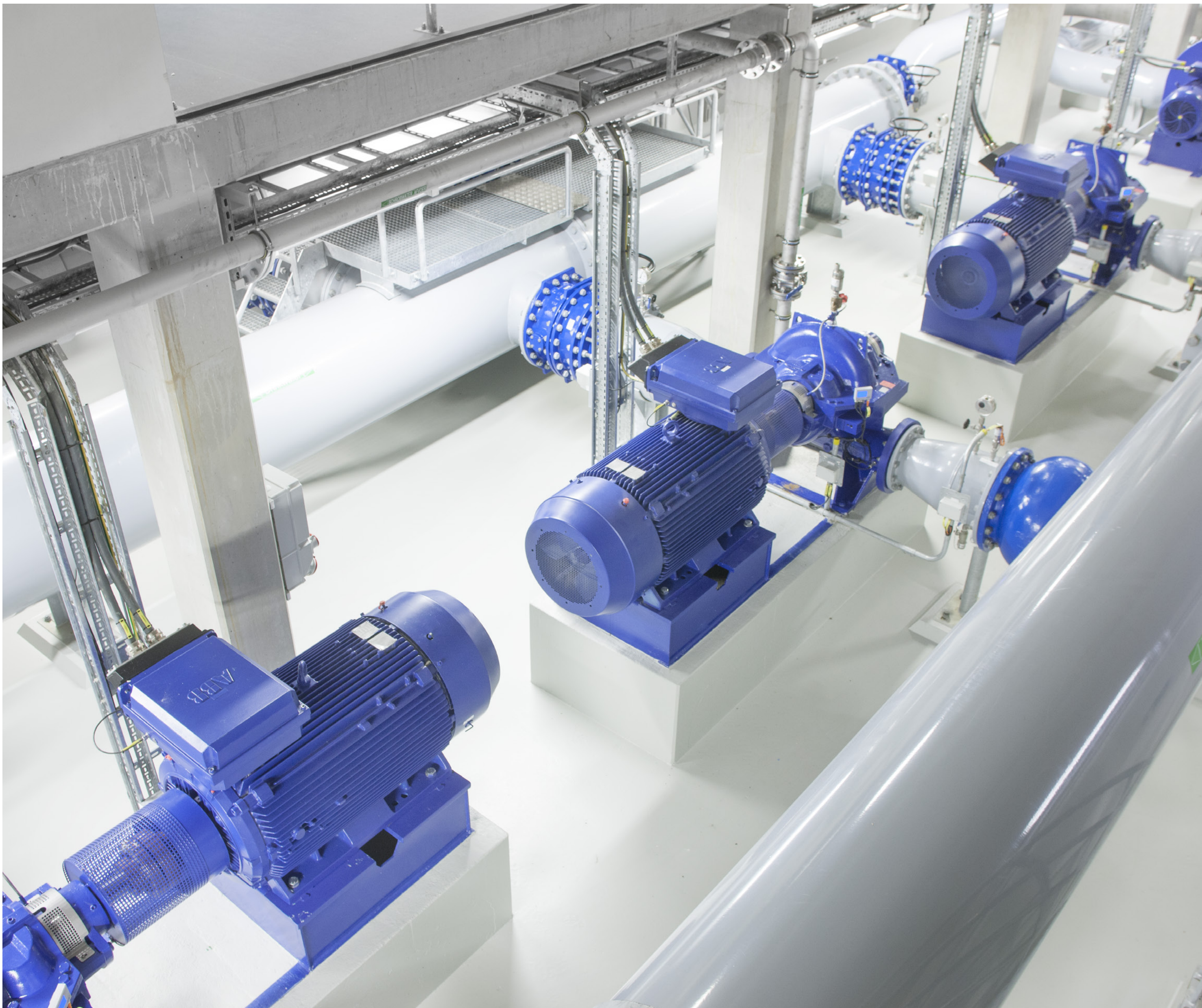
Such steps have already been taken to support the uptake of electric vehicles and renewable energy sources. It is past time to do the same for a sustainable technology that promises to deliver even greater benefits for the environment and the global economy.



The critical role of electric motors

Modern, high-efficiency motors, paired with variable-speed drives, are designed to be flexible and reliable. Yet above all, they are extremely efficient, offering significant reductions in power consumption compared with older systems. Their importance in the development of a sustainable society cannot be overstated. Since 45% of the world's electricity is used to power electric motors in buildings and industrial applications, any investment in upgrading the equipment used in these systems will yield significant rewards in terms of efficiency and sustainability.[8]

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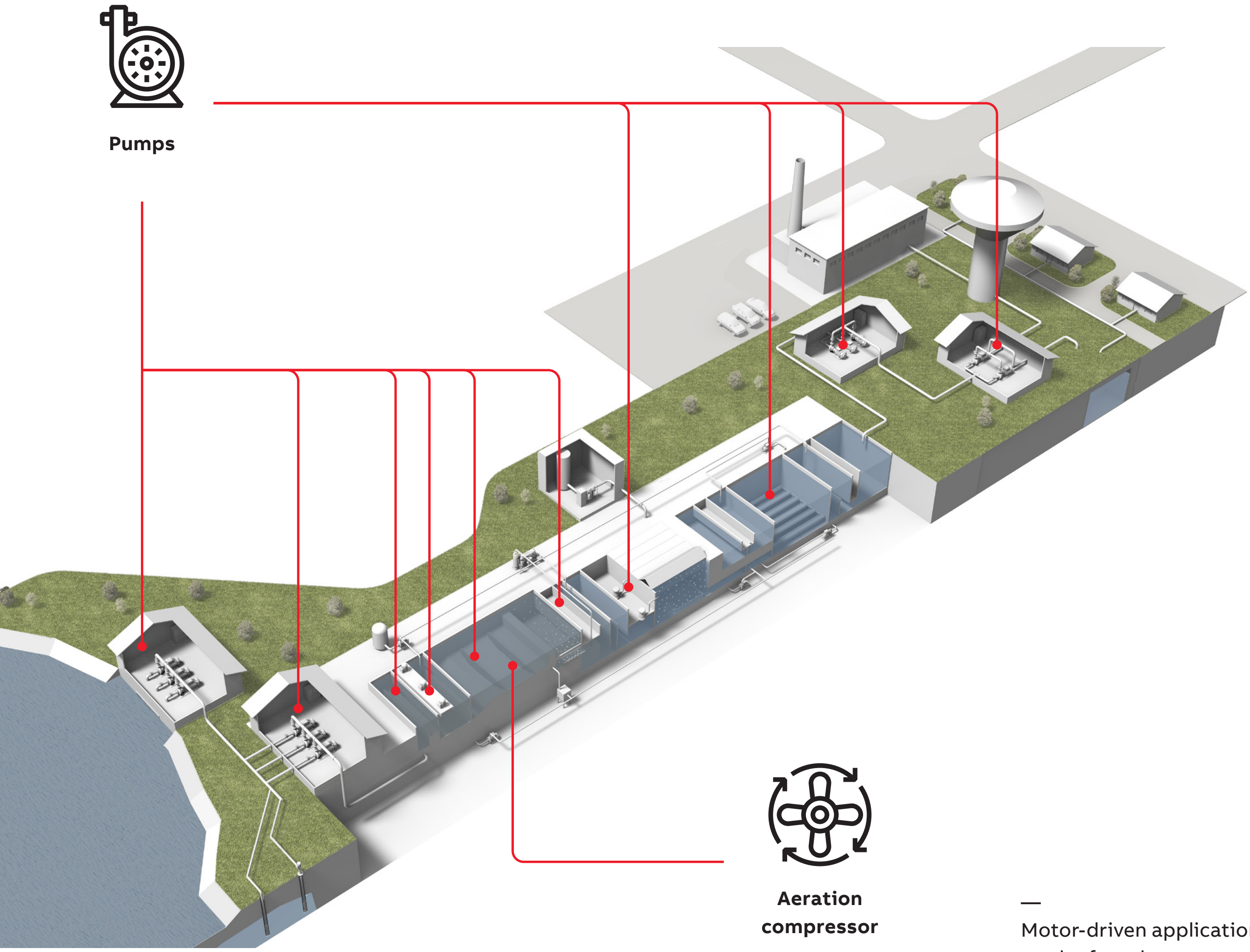
While they may not be highly visible, electric motors are ubiquitous, an integral part of global industry and our everyday lives.



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Motor-driven applications can be found at every stage of water treatment.

Small motors are found in the compressors used in air conditioners and refrigerators, in car windows, computer printers, the cooling fans of electronic appliances, and countless other common devices. Mid-sized motors appear in heating, ventilation, and air conditioning (HVAC) systems, as well as in elevators, rapid transit vehicles, and electric and hybrid automobiles. They are used extensively in industry, for pumps, conveyors, fans, and mechanical motion of all kinds. The largest electric motors are found in railway engines, cable cars, ship propulsion systems, and heavy equipment of the sort used for mining and paper mills.

While large motors, drawing more than 375 kW of power, represent only 0.03% of all motors in use, they nonetheless account for about 23% of all electric consumption by motors globally, or 10.4% of all electric power usage. The smallest motors, with an output of less than 0.75 kW output, account for just 9% or so of electric motor power consumption.[9]

The majority of electric power consumed by motors is used by mid-sized motors. Many of these are larger than necessary for the applications at hand and are often run at full speed, even when the extra power is not needed.

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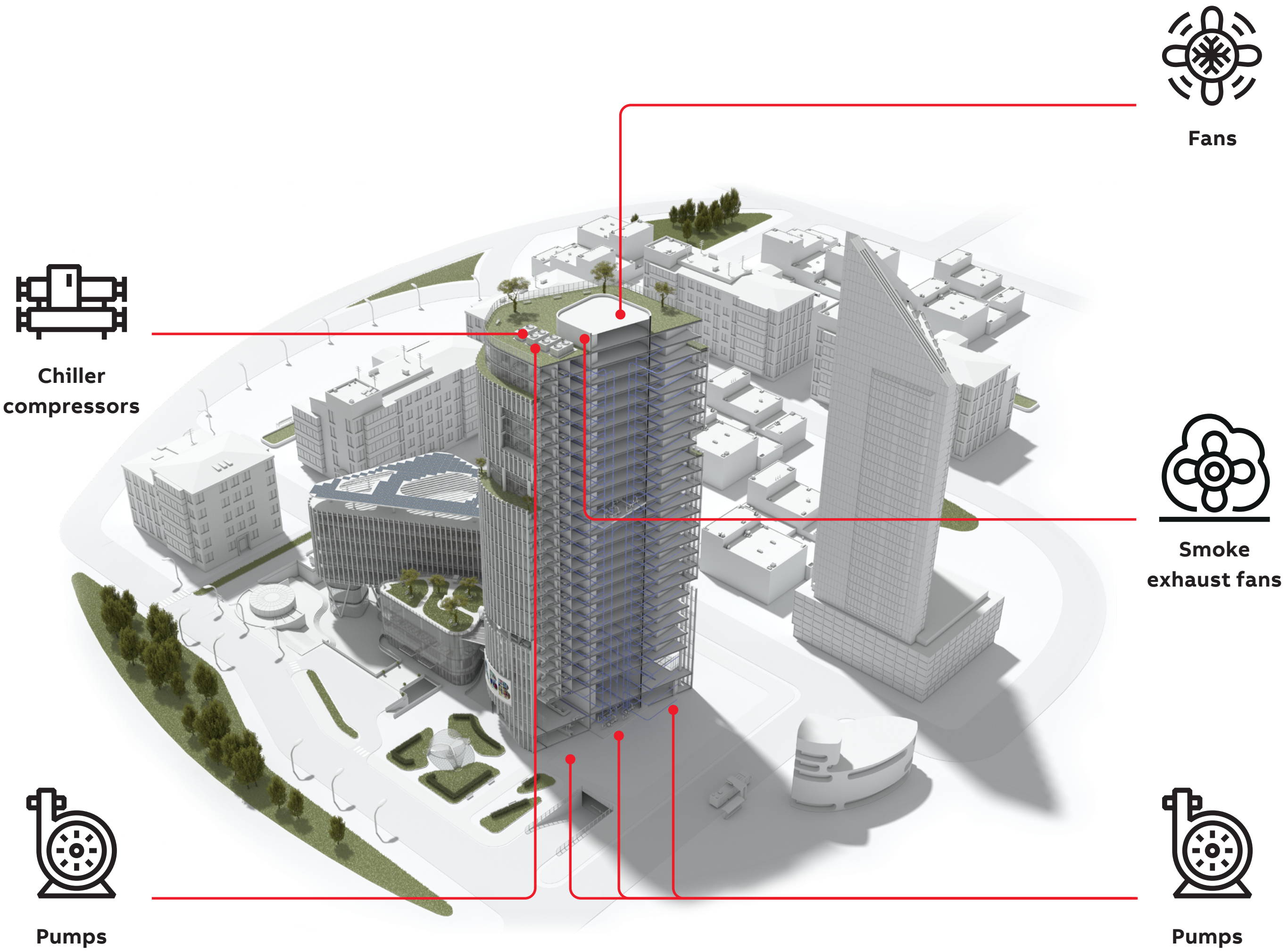
Roughly 75% of the industrial motors in operation are used to run pumps, fans, and compressors, a category of machinery that is highly susceptible to major efficiency improvements.[10]

The potential reductions to be achieved in energy consumption and carbon footprints are dramatic, to say the least.



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Motor-driven applications are found throughout buildings to provide heat, ventilation and air conditioning.

Motors are at the forefront of global efforts to improve efficiency and reduce emissions

The trend in industrial engineering has been toward the utilization of more and smaller motors, optimized for specific tasks. Matching the output of a motor to the maximum power required for a task already represents a major step toward achieving greater energy efficiency. Arguably this efficiency can come at the cost of greater complexity. But in the latest systems, this complexity is effectively addressed by implementing smart sensors and internet-connected monitoring systems that can alert operators when any given motor shows signs of needing repair or replacement.

At the same time, modern motor designs offer higher efficiency than in the past. A motor's efficiency equals its mechanical output power divided by its electrical input power. The most common type of electric motor in use is the alternating current (AC) induction motor, based on the designs developed in the 19th century by Galileo Ferraris, Nikola Tesla and Mikhail Dolivo-Dobrovolsky. These motors have steadily improved over the years, based on changes in materials and stator and rotor designs.

It may be worth pointing out that even an ordinary induction motor is highly efficient compared to any internal combustion engine. The thermal efficiency of the engine powering a typical passenger car is rarely better than 35%.[11] Almost any electric motor of comparable output achieves an efficiency of more than 90%.

Modern induction motors are available at very high levels of efficiency. Motor efficiency is rated according to a scale published by the International Electrotechnical Commission (IEC). Motors categorized as IE1 or IE2 are comparatively inefficient. A 200 kW AC induction motor that meets the IE3 standard achieves roughly 96% efficiency. Some of the very latest motors meet the IE4 standard, which specifies energy losses about 15% lower than those delivered by IE3 motors, and the more recent IE5 "ultra-premium efficiency" motor represents the highest level of efficiency that has been met by any current design.

International Efficiency (IE) standards stipulate the energy efficiency of low voltage AC motors. These IE codes serve as a reference for governments who specify the efficiency levels for their minimum energy performance standards (MEPS).

1	2	3	4	5
IE1 **Standard Efficiency**	**IE2** **High Efficiency**	**IE3** **Premium Efficiency**	**IE4** **Super Premium Efficiency**	**IE5*** **Ultra Premium Efficiency**

Five levels of motor efficiency

***The IE5 class has not been specified in the standard yet, but some manufacturers have already developed motors that will be compliant.**

Too many motors in use today do not meet these standards and rely on older, IE1 or IE2 designs. It presents another challenge that many of these motors are over-dimensioned to the uses they serve. They frequently deliver much more power than required, which wastes energy. Considerable gains in efficiency may be achieved simply by deploying motors that are correctly dimensioned for the application in question.

Alongside induction motors, some highly efficient newer motor designs are establishing themselves as practical alternatives. Among these is the synchronous reluctance motor, which combines the performance of a permanent-magnet motor with the simplicity and service-friendliness of an induction motor. Unlike permanent-magnet motors, synchronous reluctance motors do not require the use of rare-earth-based components. Instead, they achieve a maximized reluctance torque from a simple but robust rotor design.

Today these innovative motors are both practical and remarkably efficient, capable even of meeting the proposed IE5 target, first outlined in 2016.[12] It is estimated that, if 80% of today's installed industrial motors were replaced with IE5 ultra-premium efficient motors, 160 terawatt-hours of energy per year would be saved, equivalent to more than the annual power consumption of Poland.[13 i 14]

Even as the world seeks to increase energy efficiency in general, new applications have emerged that place a premium on efficient motor designs.

This is certainly true of any application that relies on batteries to power a motor. A battery-powered automobile, for example, does not have the luxury of wasting power drawn from the grid but must be carefully designed to minimize consumption while maximizing the range and power available to the driver. This need is motivating a steady stream of new technological breakthroughs amid global growth in electric vehicle sales, a trend expected to continue.

State-of-the-art traction technology, energy storage systems and e-drivetrain solutions are now enabling an expanding array of emission-free transport options in the areas of rail, buses, heavy vehicles and marine vessels. Zero-emission boats and hybrid ferries are even beginning to make an appearance in the world's commercial waterways. New innovations in motor design have a major part to play in enabling the rapid uptake of all of these forms of electric mobility.

The underappreciated role of variable-speed drives

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While there are significant efficiency gains to be reaped from upgrading a motor, still greater energy savings are achievable when a high-efficiency motor is used in combination with a variable-speed drive.

A variable-speed drive serves to control an electric motor in such a way as to optimize its operation. It accomplishes this by adjusting the speed and torque of a motor as it operates to match the system's load requirements. With the right drive, an electric motor will run only as fast as is called for by the underlying load, leading to significant power savings.

Drives control the speed of an AC motor by varying the frequency and voltage of the power being fed to it. The earliest drives, developed in the early 20th century, were based on mechanical designs.

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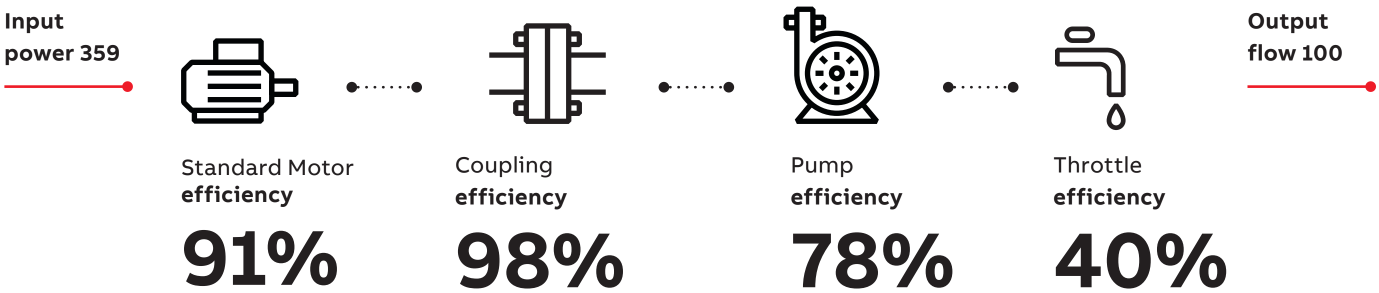
Conventional pumping system

System efficiency = 28%



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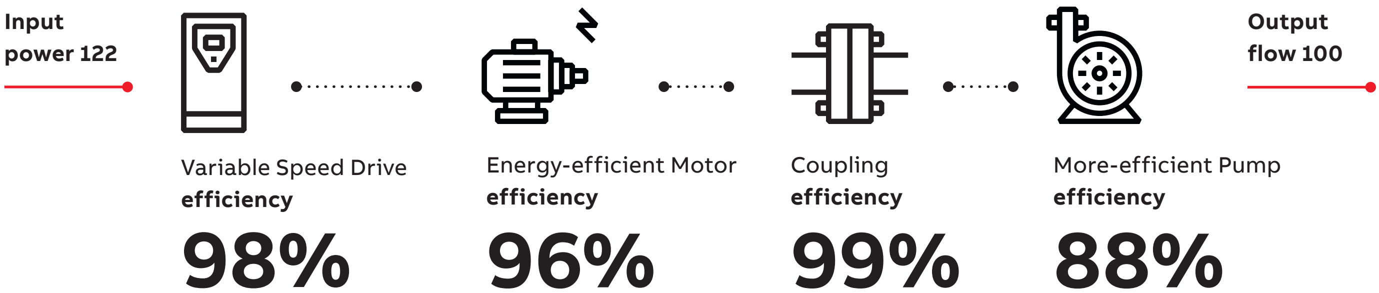
Energy-efficient pumping system

System efficiency = 82%



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The numbers in this example are based on 60% nominal design flow

As solid-state electronics have advanced in recent decades, drives have become dramatically more sophisticated and less expensive. In spite of these advances, they have been deployed at a modest pace thus far. It is estimated that 23% of the world's industrial motors are presently equipped with a variable-speed drive.[15] That figure is expected to increase to 26% over the next five years, but substantial additional savings could be achieved if the rate of adoption increased. Industry experts have suggested that roughly 50% of industrial motors would benefit from being paired with a drive.[16]

Without being controlled by a drive, many motors run at full speed even when the load requirements are minimal. For example, to control the mechanical power generated by the motor in pumping applications, a technique called "throttling," is used which is akin to reducing the speed of a car by applying the brakes without letting up on the accelerator. This represents a substantial waste of energy.

When added to the existing motor of a pump, fan or compressor, a variable-speed drive can typically reduce power consumption by 25%.[17]

The impact of digitalization and connectivity

Another technological development that is poised to improve the efficiency of the world's electric motors can be found in digitalization and connectivity – the "industrial Internet of things." By attaching wirelessly connected sensors to existing motors, it becomes possible to monitor their performance transparently and remotely. In a complex industrial installation or a large building's HVAC system, the resulting data can make it possible to optimize processes and realize significant efficiency gains and energy savings.

When the motors being monitored are controlled by variable-speed drives, they truly become smart motors, since they can then be controlled remotely or even automatically, further optimizing performance, system efficiency and energy savings. Data provided by the sensors can be analyzed along with other control data and then used by a central control system as the basis for real-time adjustments to the entire installation.

Potential benefits and the way forward

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It has been estimated that, if all of the more than 300 million industrial electric motor-driven systems currently in operation were replaced with optimized, high-efficiency equipment, global electricity consumption could be reduced by up to 10 percent.[18]

So the potential gains associated with modernization are large.[19] Yet practical challenges remain to be overcome if we are to realize these gains.

Regulatory policies are among the main drivers of industrial investment in energy efficiency around the globe. This is particularly true of the rules implemented by large industrial producers, such as China, Europe, India and the United States. Properly designed rules and incentives can play a major part in promoting the adoption of high-efficiency motor technologies.

Another major consideration is payback periods, as investments in energy efficiency must compete with the potential returns from other investments.[20] An investment in motors and drives is often an attractive proposition because of their ease of installation; they can generally be installed without requiring any additional modification of an existing industrial system. Yet the payback timeline depends heavily on energy prices. In periods of higher energy prices, we can expect to see increased investment in more efficient equipment. At present, the financial incentives are working against rapid uptake.

Yet the fact remains that deploying more drives and the latest electric motor designs represents a tremendous opportunity as the world seeks to achieve greater energy efficiency. The gains to be realized are ultimately likely to account for more than 40% of the reduction in greenhouse gas emissions required by 2040 in order to reach the climate goals established by the Paris Agreement.[21]

Some successful recent projects and their impacts

There is no shortage of examples for how high-efficiency motors are already generating economic and environmental benefits around the globe. We will cite just a few of them.

Asia
In 2018, India's National Motor Replacement Program (NMRP) undertook pilot studies of 36 motors in the cities of Ahmedabad, Surat, Jamnagar and Mumbai. By replacing standard efficiency motors with premium efficiency IE3 motors in compressors, pumps, fans and blowers used in the brass, textile, chemical and automobile industries, it observed power savings across all pilot installations. The NMRP began to explore the potential impact of upgrading 5,000 standard efficiency motors at large companies and SMEs around the country. It concluded that the action would achieve annual energy savings of 9,150 MWh, an annual cost savings of $902,112 and an annual CO_2 emissions reduction of 8,050 tons. The NRMP estimates that capturing the country's entire market would lead to energy savings of approximately 22 million MWh and emission reductions of 18.3 million tons of CO_2 per year.[22]

Europe
At the Nordzucker AG sugar refinery in Uelzen, Germany, regenerative industrial drives from ABB are being used to operate the site's sugar centrifuges at an unprecedented level of efficiency. The centrifuges play a key role in the process of making sugar, separating crystalline sugar from a sticky syrup. The motors that drive the centrifuges must accelerate a batch at maximum speed full torque for about 15 to 20 seconds before slowing down the centrifuge as quickly as possible. The drives enable them to do this without overheating. Even better, their regenerative capability makes it possible to feed the braking energy of the motors back into the grid. Compared to other braking methods, these drives save significantly more energy.[23]

Americas
The Enercare Centre at Exhibition Place in Toronto is the ninth-largest convention center in North America, with more than one million square feet of space. It's also LEED Platinum-certified and places a premium on eco-efficient operations. But its size means that its HVAC system uses more than 380,000 kWh per year to power the pumps that circulate water to heating and cooling equipment throughout the facility. In 2018, it equipped 11 large pumps with modern HVAC drives. The project delivered immediate results, reducing pump energy consumption by up to 38%.[24]

The global impact of ABB's high-efficiency motors and drives

As a leading supplier of low and medium-voltage motors and drives, ABB frequently assesses the net impact of the equipment it has produced on global energy efficiency. Over the course of 2020, ABB's installed base of high-efficiency motors and drives enabled 198 terawatt-hours of electricity savings (or more than three times the total annual consumption of Switzerland).[25] By 2023, it is estimated that the expansion of ABB's installed base of motors and drives will enable customers to save an additional 78 terawatt-hours of electricity per year, slightly more than the total annual consumption of Chile.

As a Group, ABB is committed to enabling its customers to reduce their annual emissions of CO_2 by an additional 100 megatons from 2021 to 2030.[26] In addition to motors and drives, the company is using digital connectivity and artificial intelligence to improve the efficiency and performance of a wide range of technologies such as machines and robots, as well as production sites, vessels and mines. These connected solutions also prolong the lifetime of equipment, helping to preserve resources. ABB also intends to lead by example – by achieving carbon neutrality in its own operations. ABB will do this by continuing its transition to renewable sources of energy, improving energy efficiency across its factories and sites, and converting its vehicle fleet to electric or other non-emitting alternatives.

198 **TWh**
of electricity savings

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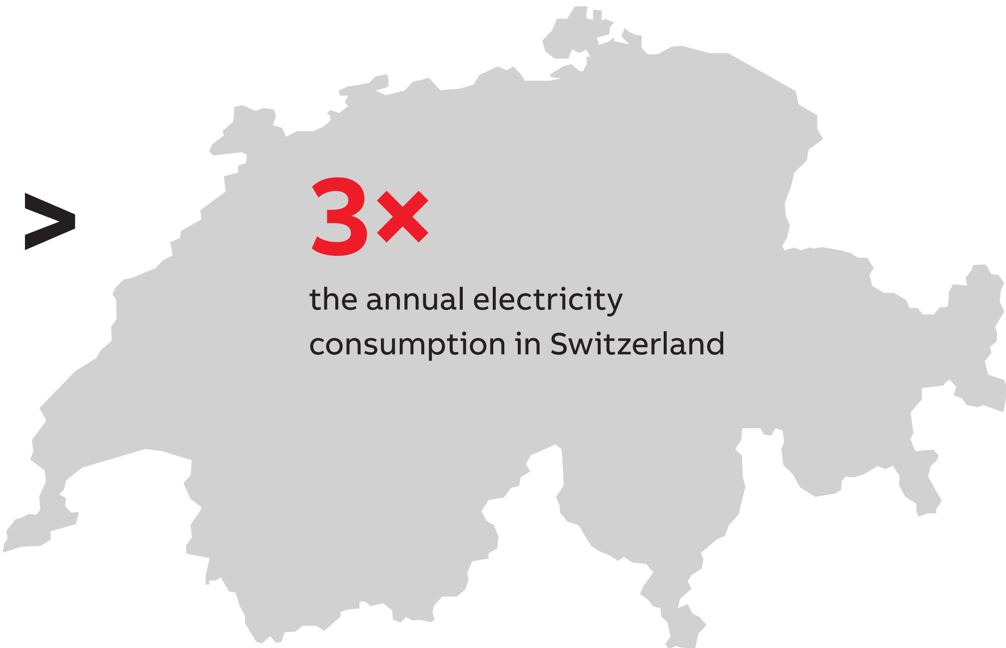

Conclusion

The technology that the world needs to dramatically improve energy efficiency is in hand. Much of it, such as high-efficiency motors and drives, is well established and time-tested. Accelerating the adoption of these existing technologies – in industry, cities, and transport – would achieve significant energy savings around the world. For that reason alone, high-efficiency motors and drives should be of great interest to the investment community, which increasingly views sustainability as a part of its investment criteria.

By promoting their adoption through tax incentives, public investment, and system-based regulatory imperatives, governments can spur further private investment and research and move the world closer to achieving the climate goals established by the Paris Agreement.

The benefits of greater energy efficiency go well beyond the fight against climate change. They contribute broadly to environmental conservation, cleaner air and water, better public health, energy independence, and stronger economic growth and development. Since the start of the industrial era, improvements in productive efficiency have always led directly to periods of economic expansion. With the latest technological advances, we are embarking on an era in which greater efficiency contributes simultaneously to economic growth and environmental protection. Accelerating the adoption of these solutions is simply common sense.

While the challenges ahead are substantial, they are not insurmountable. With adequate investment and appropriate legislation, it should be possible over the coming decades to make major progress towards the climate goals of the Paris Agreement, as well as on the UN's Sustainable Development Goals. As the environmental and economic impacts of obsolete technologies have grown, it is clear just how much we stand to gain by embracing new and improved ways to manufacture goods and operate our buildings and transport networks. The faster we can make this happen, the more we all stand to benefit.

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