Electric Motor Systems

Siemens will support the city of Vienna in optimizing its main sewage plant in terms of energy.
Source: Siemens

The role of motor systems in the energy transition

Electric motors are a major component of the technological world in which we are living. Even the most modest European households today contain easily ten electric motors. Apart from the obvious ones (the washing machine, vacuum cleaner and kitchen mixer), there are the pump systems in the heating boiler, hot water boiler and dishwasher, as well as fan systems in bathroom ventilation, computer and microwave. In industry, electric motors are even more widespread and often hidden in closed systems such as fans, pumps or compressors.

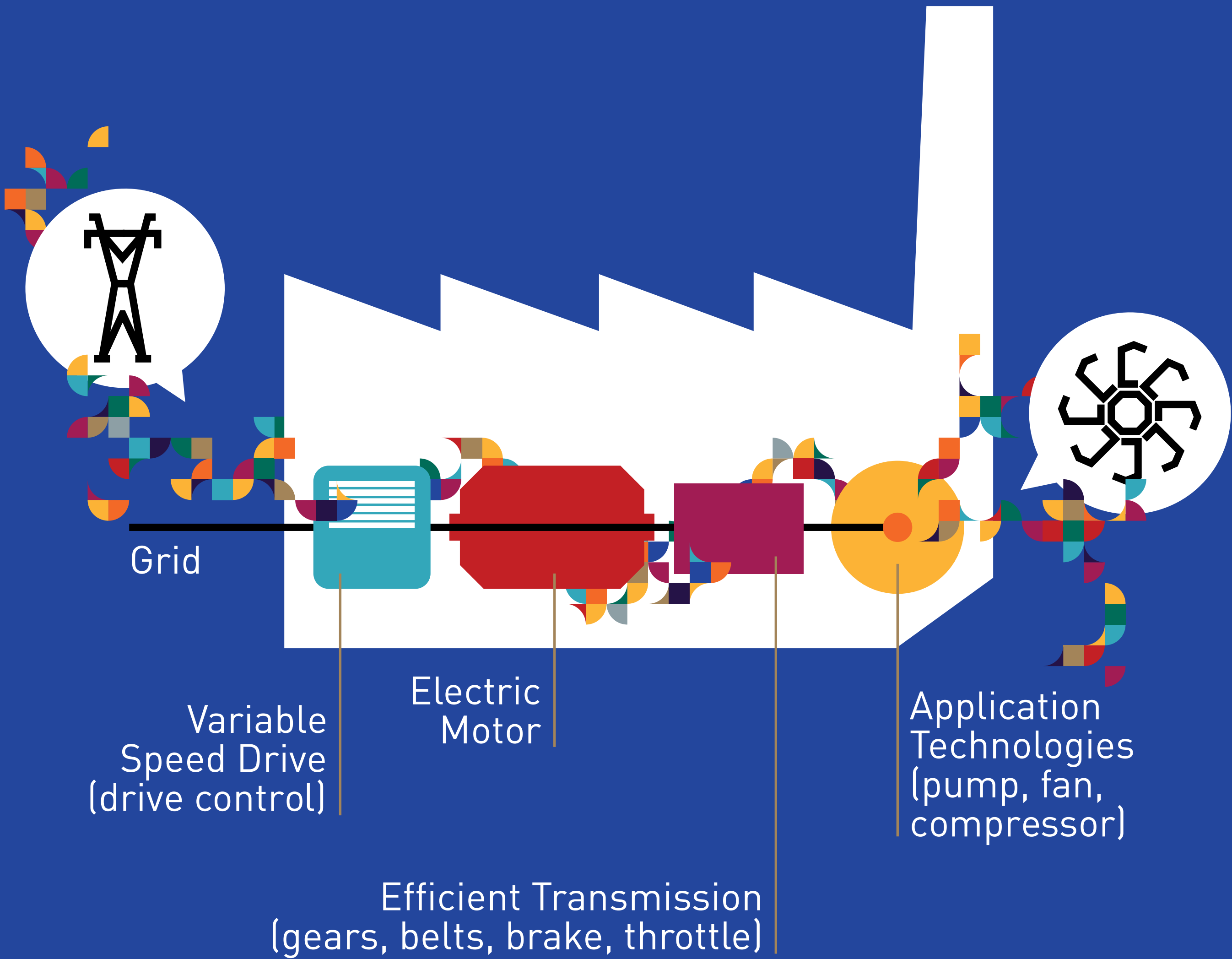
Electric motor systems currently use 53% of global electricity and 8% of global energy consumption.

In the transition towards a zero-carbon energy system, the role of electric motors will grow even further. A large part of the transition away from fossil fuel end-use to electricity-generated by renewables will occur by adopting heat pumps and electric vehicles. Both are approximately three times as efficient as their fossil fuel counterparts and driven by an electric motor. In the zero-carbon economy scenario, the estimated total share of motor systems will quadruple from 8% to 32% of all energy end-use. Therefore making those systems highly energy efficient is imperative.

The technology to make motor systems more energy efficient is available on the market and its adoption is mostly beneficial from a life-cycle costing perspective. Good work has been done: since 2011, minimum efficiency performance standards (MEPS) for the major motor categories are mandatory in the EU. Nevertheless, there is a large savings potential that could be tapped into through better adoption of existing standards, the extension of MEPS towards other motor categories, and more emphasis on an overall electric motor system's approach.

Indeed, the electric motor does not function in isolation: the motor driven unit (MDU) consists of the electric motor, sometimes controlling equipment such as a soft starter or variable speed drive (VSD), supporting mechanical equipment (gear, belt, clutch, brake...) and the application it is driving (pump, fan, compressor). The motor system also includes all other components that suffer from energy losses while executing its function (water or air ducts, throttles, valves). Optimizing this entire motor system is the best way to minimize energy use and CO_2 emissions.

MOTOR DRIVEN UNIT



1. Electric motors and the applications they drive (pumps, fans and compressors) are the single largest user of electricity, consuming > **2.5 times** as much as lighting.

2. Electric motor systems use over **50%** of global electricity and around **70%** of global industrial electricity.

5. Electric motors are everywhere - a modern home contains at least 50 motors; a luxury car has over 100 motors of different sizes.

6. By 2040, the annual global electricity savings for motors and motor systems could reach up to **3,050 TWh** per year.

Energy efficient motor driven systems can save Europe over 100 Mt GHG emissions a year.

3. Better energy efficiency regulations could reduce global electricity demand for electric motors by **24%** in agriculture, buildings, and industry.

4. Electric motor-driven systems used in heat pumps and electric vehicles save a factor three in final energy compared to combustion technologies.

7. New and existing technologies offer the potential to reduce the energy demand of motor systems across the global economy by **20% to 30%** with short payback periods.

8. Over **50%** of all electric motors are almost twice as old as their operating life expectancy which is between 20-30 years.

9. The global market for electric motors is expected to expand by **2.5%** per year until 2019, primarily driven by growth in developing countries.

10. **40-60%** of all motor systems would benefit from the proper use of Variable Frequency Drives (VFD) to improve the energy efficiency of industrial motor systems.

Sources: OECD, IEA, 4E EMSA, Swiss Topmotors Program, ECI, Dutch Green Deal Efficient Motor Systems.

1. **Reinforce market surveillance of existing regulation.**
   There is a lack of capacity in the EU to check motor compliance. Given the number and variety of motors, certifying existing labs of manufacturers seems the most pragmatic way. The US system for market surveillance can serve as a good example that includes fines for non-compliance, a website for reporting non-compliant motors, random compliance testing, and manufacturers who can take action to measure motors of competitors in their labs (if a motor is non-compliant, the result is verified by an independent laboratory).

2. **Reinforce policy-maker involvement in international standardization.**
   Nearly all policy-making concerning electric motors (whether MEPS, labelling or energy audits) are directly or indirectly based on standards. Involving policy-makers in the process of standardization committees will facilitate the development of appropriate test methods, performance metrics and efficiency classifications, while keeping pace with government objectives. This will lead to standards that are sufficiently reliable, robust and fit for policy implementation and could increase overall harmonization.

3. **Expand MEPS to other motor categories.**
   In line with IEC 60034-30-1, small motors (0.12-0.75 kW) and large motors (375-1,000 kW) should be included in the MEPS to combine motor and VSD to be equally stringent; motors without VSD should also be adopted.

4. **Promote a larger saving system's approach.**
   Beyond the physical electric motor, assessing the energy efficiency of the motor driven unit or the entire motor system is difficult because it involves interactions between electrical, mechanic and electronic components and can depend on local circumstances such as the motor load. Harvesting the entire motor system savings potential could be achieved through mandatory motor system audits. A system's approach can also be promoted through propagation of energy management principles and through education and training initiatives.

5. **Connect energy and carbon emission savings with the principles of the circular economy.**
   The energy transition leads to an increased use of material in electric motors (higher number of motors + material use in high efficient motors). This can be made sustainable through the principles of the circular economy, which have been defined by regulators around the world and notably in Europe. They translate into a reluctance to use rare earth materials, strong end-of-life requirements (recycling) and strengthened management systems.

Michael Björkman

Technical Director, Marketing, Danfoss Drives

Why are motors important to decarbonising Europe's energy system?

Motor systems utilize more than half of the world's total electrical energy so the efficiency of these systems is crucial when analyzing the possibilities to save energy in the future. The components of motor systems (motors and variable speed drives) already have decent efficiencies. Motors are required to meet or exceed the efficiencies defined in IEC 60034-30. The efficiency of variable speed drives is increasing to above 96%, and as higher efficiency for these power electronic devices implies lower losses, hence smaller and more compact products are possible.

The third main component of motor systems (the driven machine) offers at least an order of magnitude higher potential energy savings. Downthrottling is most often used as a regulation mechanism, but it wastes energy, that could be saved by simply slowing down the machine. Pumps and fans are the best candidates – if you can slow down your pump by 20% then the output flow will be reduced by 20% but the power required to drive the system can be reduced by almost 50%.

The extended product approach as defined in standards (IEC 61800-9-2/EN 50598-2) helps customers quantify the potential energy savings.

How can Europe ensure leadership in efficient motor systems?

Europe has been active in standardizing efficiency requirements for motor systems. EN 50598 series – a standard on how to determine the efficiency of motor driven systems – was published in 2016 and has now been converted into a global IEC standard: the IEC 61800-9 series. The foundation for a potential regulation of the efficiency requirements is now in place. The behavior of the driven machine is the subject of standards from ISO, and the first drafts of a standard for pumps will soon be published. The efficiency requirements in the forthcoming Lot 30 are a good start but they only address the motor and variable speed drive, not the whole system which is the key to energy efficiency.

How will the digital and circular economy will impact the motors sector?

The circular economy initiative will have some impact, specifically on the motor side. There the challenge is to achieve a balance between the efficiency requirements and the material requirements – as a motor designed for higher efficiency will contain more material. For a normal asynchronous motor, the efficiency can augment by increasing its size or by changing the magnetic material used. Alternative motor designs, such as permanent magnet motors, improve the efficiency at the cost of more expensive material and manufacturing methods. These alternative designs also require the use of a variable speed drive with some additional losses.

Motor systems utilize more than half of the world's total electrical energy.

The circular economy has a different impact on the efficiency of a variable speed drive. The efficiency losses of a drive determine, to a large extent, the physical size of the product. Reducing the losses can be achieved by using newer technology and is not material dependent in the same manner as in a motor. Decreasing the size therefore reduces material usage. The materials used are unfortunately not as easily recyclable as the materials of a motor. This requires more research into cost-effective methods of reclaiming the rare and expensive materials used. Variable speed drives are by their very nature digital and will perform as intelligent sensors very close to the process, opening possibilities for further system level energy optimization.

The use of variable renewable energy sources for power generation has created the need for a smart grid with increased flexibility. How can motor systems deliver flexibility in demand?

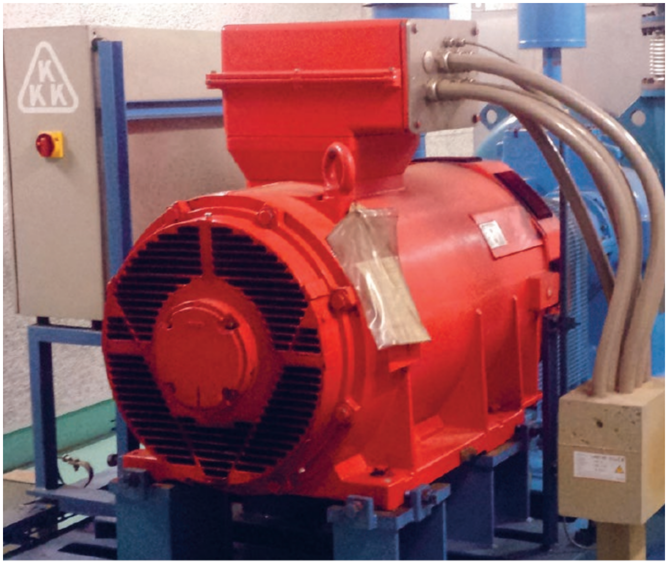
Most motor systems are controlled by some system parameter and, unless this is changed, the possibilities for demand flexibility are low. However, many applications exist where the requirements are not always carved in stone – for example it is possible to reduce the fan speed in a HVAC system if there is not enough power available without immediately impacting the comfort of people in the affected areas. Similarly, some pumping systems can be turned off, if the requirements are low, without impacting users (if there is sufficient water in a water tower, no new water is required for a period of time). In the final analysis, demand flexibility comes from the application (how much flexibility it can supply) and a motor-driven system offers an easy way to interface the controlled system with the demand side controller.

DAIRY INDUSTRY
Switzerland

Moving fluids is a key expenditure chapter in the dairy industry. Optimizing the pumping systems delivers important savings: in this case, 7% of the total electricity consumption. The key action concerns the replacement of old motors by new, high-efficiency motors equipped with an electronic regulation system (variable speed drive). This delivers energy savings in the range of 66% for this concrete application, with a payback period of about 3 years. The production volume and the quality of the product were not affected. This action didn't lead to any additional complexity in terms of operation and maintenance.

WASTEWATER TREATMENT
Switzerland

This water treatment plant processes 60 million cubic meters of waste water per year, from a city of 720 000 inhabitants. Motors driving pumps and compressed air consume 26 GWh of electricity per year. The optimization of the motor systems has delivered 15% energy savings, which allowed to recover the investment in about 2 years. This project was carried out in the context of a broader technical and energy renovation programme, which carefully analyzed the pumping systems and compressors. The actions included the integration of a smart control to better regulate the load of motors according to the waste water condition.



SYSTEM EFFICIENCY
Netherlands

Sugar manufacturing is an energy intensive process. An old pumping system based on 3 units was replaced by a new, high-efficiency system using only two motors (one in operation, the other is used as a backup). The new system delivered a 40% cut in operational expenses, which made possible to recover the investment within 2 years. Savings are in the order of 1GWh per year. Additionally, the factory worked on a more efficient pipe network where aspects such as friction loss in the pipe and the number of corners were investigated.

According to Green Deal Efficient Motor Systems, By implementing the new pump system, an annual saving of €105,120 can be realized. The initial investment might be high, however the break even point can be reached within a year or two depending on the initial investment. Assuming the new motor system has a life time cycle of 15 years, the total saving over a period of 15 year can be more than €1,000,000.

(Left) Redundant pumping system, a 7.5 kW motor. Source: Topmotors and Impact Energy
(Middle) Motor and compressor. Source: Topmotors and Impact Energy
(Right) Sugar refinery of the Suiker Unie in Hoogkerk, Groningen, The Netherlands. Source: Wutsje