Rethinking mixer efficiency

Beyond IE motor ratings

Motor efficiency vs. total energy efficiency in mixer selection

When choosing a submersible mixer for an application, the mixer's motor efficiency is an important factor to consider, as it can contribute to higher energy savings and lower emissions. However, mixer operators must consider the total energy efficiency of the mixer, which has a significantly greater impact on operating costs and energy usage than the motor efficiency alone. In fact, Xylem's research shows that up to 80% of a mixer's energy efficiency comes from its hydraulics.

This paper explains IE motor ratings, the importance of the mixer's overall design and hydraulics in reducing energy, and how to ensure optimal energy efficiency.

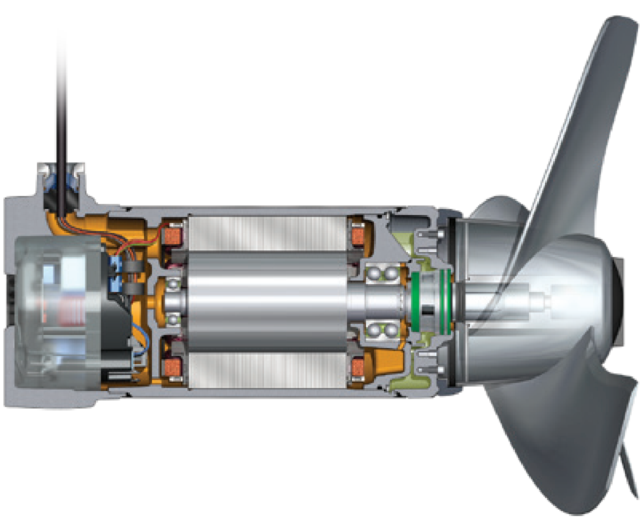
Key takeaways

- Motor efficiency is just one of several factors that determine the overall energy efficiency of a submersible mixer.
- There are no official International Efficiency (IE) motor standards for submersible motors, only equivalent ratings.
- The energy efficiency of a submersible mixer is mostly dependent on its hydraulics, how effectively it transmits energy to media.
- The industry-standard metric for comparing mixer performance and energy efficiency is the thrust of a mixer divided by energy consumption (N/kW).
- Optimal energy efficiency is achieved through a combination of motor selection, hydraulics and variable frequency drives.

The growing importance of efficiency in mixing

Rising energy costs, stricter environmental regulations, and the increasing demand for high-quality mixing results have led in recent years to a stronger focus on the energy efficiency of mixers. As energy prices continue to climb, utilities and industries are under pressure to find ways to cut costs while maintaining productivity. Additionally, regulatory bodies are enforcing stricter limits on emissions, compelling operators to adopt more energy-efficient technologies.

Furthermore, the increasing precision required in modern mixing applications—such as in biological nutrient removal in wastewater treatment—require highly efficient mixing solutions to ensure consistent and optimal results. The combination of these economic, environmental, and quality requirements makes efficient mixing more important than ever.



What do we mean by mixing efficiency?

The ultimate goal of a mixing solution should be to achieve the desired mixing result with the least amount of energy used. A starting point when evaluating mixers, therefore, could be to look at the motor efficiency of a mixer.

The efficiency of a motor is a measure of how well the motor converts electrical energy into mechanical energy. It is expressed as a percentage and calculated by dividing the output power (mechanical power) by the input power (electrical power) and multiplying by 100. For example, if a motor receives 100 watts of electrical power and produces 90 watts of mechanical power, its efficiency is 90%.

Mechanical power, however, is only one aspect of mixing efficiency. Mixing efficiency refers to how effectively a mixer achieves the desired level of homogeneity or uniformity in the material being mixed. It involves the thorough distribution of components within a mixture to meet specific process requirements. To achieve optimal mixing efficiency, you must look at the total design of the mixing system, including mixer positioning, optimal hydraulics, consideration of the media being mixed, and mechanical power.

The importance of efficiency classes for electric motors

Mandatory efficiency classes for electric motors have become increasingly common, particularly in the European Union. For example, all electric motors in the EU between 75kW and 200kW had to meet the IE4 efficiency-class requirements by July 2023. The International Efficiency (IE) class system, set by the International Electrotechnical Commission (IEC), defines the efficiency of electric motors according to: IE1 - Standard efficiency, IE2 - High efficiency, IE3 - Premium efficiency, IE4 - Super Premium efficiency, and IE5 - Ultra-premium efficiency.

This efficiency classification system shows how much energy input a motor loses when converting electric energy into mechanical energy. While certain IE1-rated motors can fail to convert 12% of its energy into mechanical energy, the IE3-rated motor could lose only 6 or 7% of its energy. An IE4 motor may lose 4% of its energy, and an IE5 motor may lose only around 3%.

Upgrading from an IE1 motor to an IE3 motor, for example, could significantly reduce energy consumption. The energy reductions from upgrading from an IE3 to an IE4 or IE5 motor, however, can be less significant, and the motor rating alone should not be the determining factor in improving the overall mixing efficiency of an application.

Efficiency classes for motors in submersible mixers

When comparing motor efficiencies, it is important to note in the IE classification standard (IEC 60034-30-1), submersible motors are excluded, meaning that there are currently no applicable testing standards for these motors. For this reason, manufacturers of submersible mixers list motors as “IE3 equivalent” or “IE4 equivalent.” Each manufacturer may have a different method of testing the efficiency of its motors, which can make motor performance and efficiency ratings difficult to verify and compare.

A submersible motor cannot be tested in the same way as standard IEC or NEMA motors. Removing the motor from the pump will affect its cooling and operating temperature, which will impact the motor efficiency. Prolonged testing without proper cooling can cause the motor to overheat, resulting in failure. Therefore, existing motor test standard does do not allow for accurate efficiency measurements.

Due to the requirement for submerged operation, the pump and motor feature mechanical seals that increase

losses if they are not removed. Submersible motors also often have a heavier bearing arrangement than IEC or NEMA motors, which creates additional losses

Current motor test standard, IEC 60034-2-1 does not provide a test method defining how to manage there extra losses to deviations in test temperatures. Given the growing interest in energy efficiency, a standardized testing method may be determined in the future for submersible motors.

A better way to compare mixing and energy efficiency

While motor efficiency is an important factor when considering energy efficiency, the mixer's thrust-to-power ratio is the industry-standard method for comparing the overall efficiency of submersible mixers. This metric evaluates how much thrust (or mixing force) the mixer generates for each unit of power consumed. The thrust-to-power ratio (N/kW) directly measures the effectiveness of the mixer in converting electrical energy into useful mechanical work.

Unlike efficiency classes, which primarily focus on the energy conversion within the motor itself, the thrust-to-power ratio considers the entire system's performance, including the interactions between the motor, propeller, and mixing environment. This holistic approach is crucial for submersible mixers, which operate in complex, fluid-dynamic conditions that significantly impact their efficiency and effectiveness.

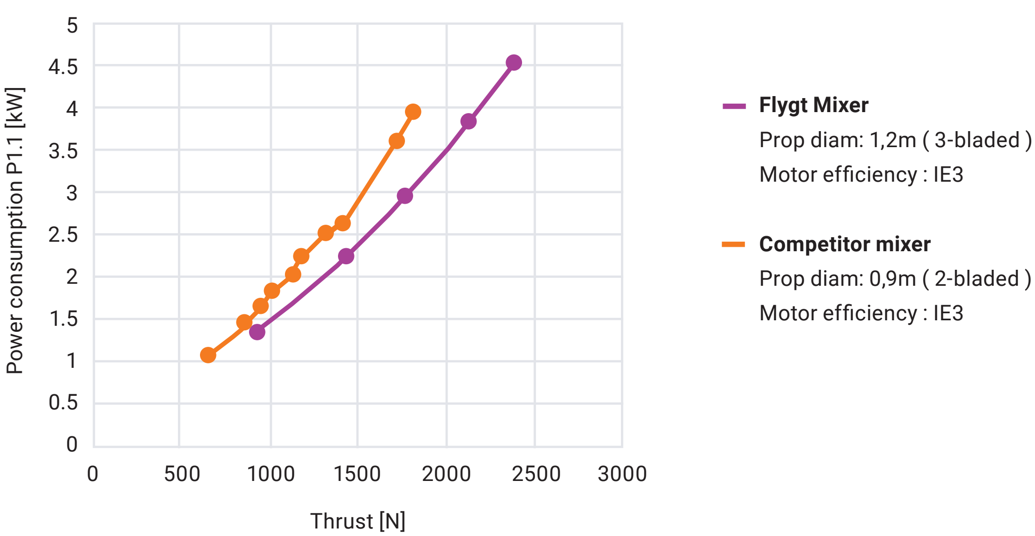
By focusing on this ratio, operators can select mixers that deliver optimal performance and energy efficiency, leading to lower operational costs and better process outcomes. This approach aligns with the comprehensive evaluation methods prescribed by ISO 21630:2007, ensuring that submersible mixers are assessed based on their actual operational capabilities and contributions to overall system efficiency. ISO 21630:2007 specifies the procedures for determining the axial thrust and power consumption of submersible mixers, enabling accurate and meaningful comparisons.

Submersible mixers can have a wide range of hydraulic efficiencies and motor class efficiencies. For example, you could have a mixer with highly efficient hydraulics and a lower IE class motor, or a mixer with a higher IE class motor but less efficient hydraulics. The thrust-to-power ratio tells you how efficient the mixer is overall.

The key role of hydraulics in mixing efficiency

Although the mixer's motor and drive unit are important factors to consider, optimizing the hydraulics of the mixer is one of the most significant factors in improving overall efficiency. Mixer hydraulics refer to how the mixer's propeller and speed affect the jet flow created in the fluid. The angle, geometry, and size of the propeller blades, as well as the overall configuration of the mixer, can improve thrust and minimize energy losses. Roughly 80% of a mixer's total efficiency, in terms of energy use and mixing results, depends on the mixer's hydraulics.

Performance comparison : Flygt mixer vs Competitor mixer



There are several key elements to consider in the design of a mixer's propeller. For example, the angle and geometry of the propeller blades should be tailored to the specific media being mixed to maximize the transfer of energy into effective mixing action. The design of propeller blades for mixing water typically focuses on achieving high flow rates and minimizing drag, with an emphasis on smooth and efficient fluid movement. In contrast, for biogas mixing, propeller blades need to be optimized for handling higher viscosities and variable solids content, requiring robust and often more complex geometries to ensure thorough mixing and to prevent clogging.

Regarding the size, thickness and number of propeller blades, larger propeller diameters generally improve thrust, and thinner blades reduce drag, making the mixer more efficient. While more propeller blades increase stability, and possibly efficiency, such as three blades instead of two, they could also increase the risk of clogging, depending on the media. By increasing the diameter of the propeller, the mixer can operate at a lower speed and still produce the same amount of thrust, which leads to decreased energy usage.

The rotation speed of the propeller is another important consideration. Slower rotational speeds typically result in better energy efficiency by reducing turbulence and drag, but this must be balanced with the need for adequate mixing intensity. By selecting a submersible mixer based on all these hydraulic elements and conditions, combined with an energy-efficient motor, operators can significantly lower energy consumption and improve overall mixing efficiency.

Important factors to consider in motors and drive units

Improving the efficiency of a submersible mixer and increasing its thrust-to-power ratio can be achieved by optimizing several key factors. A high-efficiency motor, designed to minimize motor losses, plays an important role. Ensuring that the motor operates within its optimal temperature range and is properly lubricated can further reduce energy losses. Using advanced materials, such as high-quality bearings, can also enhance motor efficiency.

The drive unit's efficiency also plays a vital role. Minimizing friction losses within the drive components, such as gears, seals and bearings, can be achieved by using high-precision manufacturing techniques and selecting materials with low friction coefficients. Moreover, innovative designs that streamline the transmission of power from the motor to the propeller can reduce energy losses and improve the mixer's thrust-to-power ratio.

Achieving the biggest efficiency gains with VFDs

Variable frequency drives (VFDs) present operators with an opportunity to dramatically reduce energy consumption. Aside from energy-efficient motors and optimized hydraulics, VFDs represent a paradigm shift in mixing efficiency. Previously, most submersible mixers have operated at a fixed speed, but now VFDs enable operators to manually or automatically adjust the mixer's speed based on operating conditions.

Variable frequency drives are electronic devices that control the speed and torque of electric motors. This capability allows operators to precisely match the motor's speed to the specific requirements of the mixing process. By integrating VFDs with submersible mixers, either as separate units or as built-in components, operators can significantly enhance the performance and energy efficiency of their mixing systems.

By adjusting the motor speed to match the actual demand, VFDs can lower the energy consumption of submersible mixers by as much as 50%. This precise control also minimizes wear and tear on the motor, mechanical components and propeller, leading to longer equipment life and reduced maintenance costs. As VFDs allow mixers to operate efficiently under varying load conditions, they are particularly beneficial in applications with fluctuating mixing requirements. This adaptability ensures that the mixer delivers optimal performance, without overmixing or consuming unnecessary energy.

Ensuring energy and cost savings when selecting a mixer

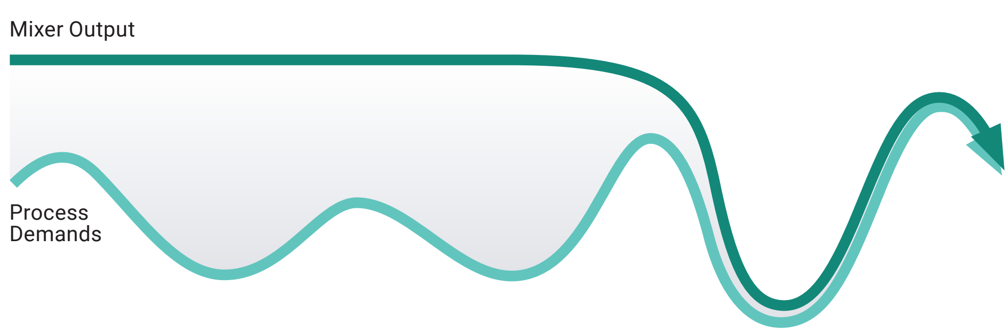
As this paper has outlined, selecting a submersible mixer based on its motor efficiency class alone will not guarantee optimal mixing performance or lower overall energy consumption. Operators must consider a wide range of criteria and features to determine the total cost of ownership for the mixer. These include the initial cost of the mixer, installation costs, operating and

Case study: Vernon Hills, Illinois, United States

The village of Vernon Hills, located in Illinois, encountered chronic issues with its existing mixers, which frequently broke down resulting in frequent downtime and costly repairs. Xylem proposed the facility switch to Flygt 4220 adaptive mixers, with built-in variable frequency drives, for more reliable operation and reduced energy consumption. The Lake County Public Works (LCPW) department agreed to a "try and buy" solution.

At the end of the trial period, data showed that the Flygt 4220 mixers used 50% less power than the utility's existing mixers. Additionally, the Flygt mixer ran during the trial period without incident and required no maintenance. As a result, LCPW ordered six more mixers with six monitoring and control panels. LCPW also has plans to replace a total of 12 mixers with the Flygt adaptive mixers.

Adaptive mixers match operating conditions reducing energy usage



Case study: Florence, Italy

The Publiacqua water treatment plant handles wastewater for more than 600,000 people, including residents of Florence and eight regional municipalities. The plant, which treats more than 65 million cubic meters of wastewater every year, has three lots of 24 sludge tanks. Each tank requires a submersible mixer to keep activated sludge in suspension.

When Publiacqua identified that one lot of tanks required new mixers, they chose 24 Flygt 4530 mid-sized mixers from Xylem. The mixer has a dependable IE3 motor with Class H insulation, and a heavy duty two-stage gearbox designed for more than 50,000 hours of operation. The mixer provides a high thrust-to-power ratio and uninterrupted, clog-free mixing, which helps the plant reduce operational and lifecycle costs. Compared to a direct-drive, compact high-speed mixer, Flygt low-speed mixers can reduce energy use by up to 50%.

Case study: Ypsilanti, Michigan, United States

When 30 mixers were failing in the aeration tanks of the Ypsilanti Community Utilities Authority (YCUA), the utility needed to find energy-efficient replacements. The plant performed an extensive energy study of aeration mixers, including Xylem's Flygt 4320 mixers, built with IE4-equivalent permanent magnet motors and integrated intelligent speed control.

The mixer's integrated VFD enables it to generate the needed thrust, while consuming as little as 50% of the power of a compact submersible mixer. The mixer's motor/drive combination also gives operators the ability to dial in any speed/thrust needed (up to 3,400 Newtons) with the press of a button. Furthermore, the mixers require maintenance only once every two years, or 16,000 hours. When looking at long-term energy costs, the utility estimated that the new Flygt mixers could potentially save them $1 million over ten years.

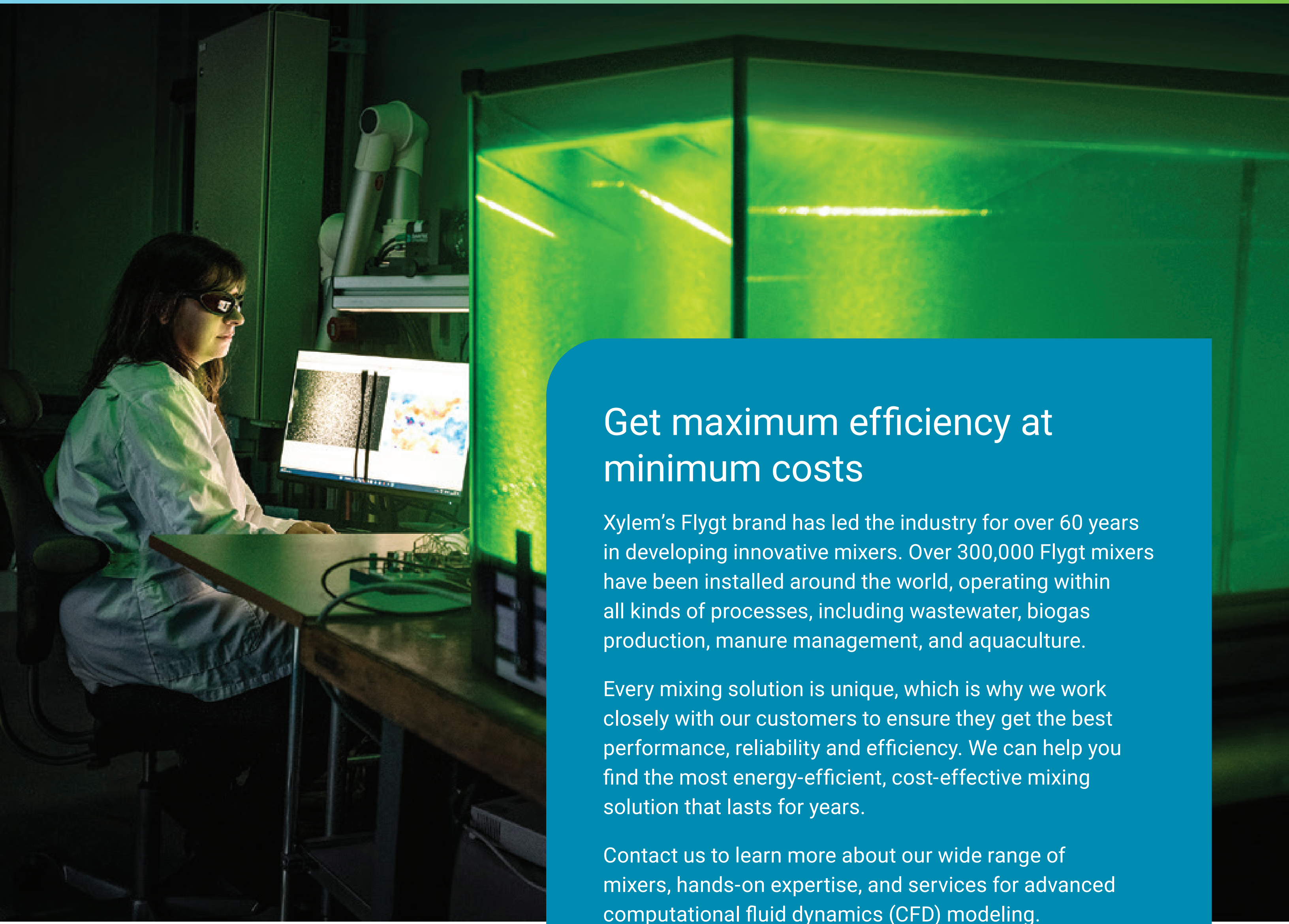
maintenance costs over its lifetime, and its thrust-to-power ratio (N/kW).

For example, a more expensive submersible mixer with a higher motor efficiency class but less efficient hydraulics may cost you more initially and in the long run than a mixer with a lower motor efficiency but better hydraulics.

A premium submersible mixer with an energy-efficient motor, optimized hydraulics, and a variable frequency drive, for example, may cost more upfront, but its increased efficiency, lower energy use and reduce maintenance costs can lead to significant savings in both the short and long term.

Here are few key questions to consider when selecting a submersible mixer:

- Consider effectiveness instead of efficiency: effectiveness = Efficiency + Productivity
- Is the mixer equipped with a high-efficiency motor?
- What is the thrust-to-power ratio of the mixer?
- Are the mixer's hydraulics optimized for my application?
- Can the mixer's speed be controlled with VFDs?
- How much total energy savings can I expect?
- What are the mixer's expected operating costs?
- Is the mixer easy to install and service?



Get maximum efficiency at minimum costs

Xylem’s Flygt brand has led the industry for over 60 years in developing innovative mixers. Over 300,000 Flygt mixers have been installed around the world, operating within all kinds of processes, including wastewater, biogas production, manure management, and aquaculture.

Every mixing solution is unique, which is why we work closely with our customers to ensure they get the best performance, reliability and efficiency. We can help you find the most energy-efficient, cost-effective mixing solution that lasts for years.

Contact us to learn more about our wide range of mixers, hands-on expertise, and services for advanced computational fluid dynamics (CFD) modeling.

About Xylem

Xylem (XYL) is a leading global water technology company committed to solving the world’s critical water challenges with innovation and expertise. Our 23,000 diverse employees delivered combined pro forma revenue of $8.1 billion in 2023. We are creating a more sustainable world by enabling our customers to optimize water and resource management and helping communities in more than 150 countries become water-secure. Join us at www.xylem.com and Let’s Solve Water.

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