Energy Efficiency in Submersible Mixers

Why It Matters

Energy accounts for about 20 percent of wastewater treatment plant operating costs. Blowers use the largest share of energy (~60 percent), but mixers are the second-largest consumer, averaging ~20 percent of plant energy. Depending on the biological process and number of mixers on site, this figure can vary by ±5 percent.

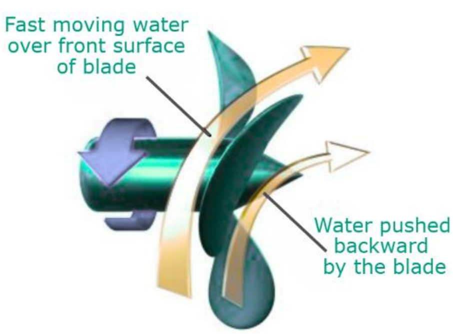
As municipalities look to reduce operating expenses and improve sustainablity, **submersible mixers** play an important role in total plant efficeiency.

How Mixers Work

Submersible mixers impart **thrust (N)** into waterwater to keep solids suspended and liquids evenly mixed.

- A motor (driver) powers the propeller.
- In **direct-drive** mixers, motor RPM determines propeller speed. Speed is fixed unless a variable frequency drive (VFD) is added, which improves control, but adds cost and maintenance.
- **Planetary gear-driven** mixers reduce propeller speed through a compact gearing system, allowing thrust to be delivered efficiently.
- **The challenge:** achieving required thrust for mixing while using the least possible energy.

Key Factors Influencing Efficiency



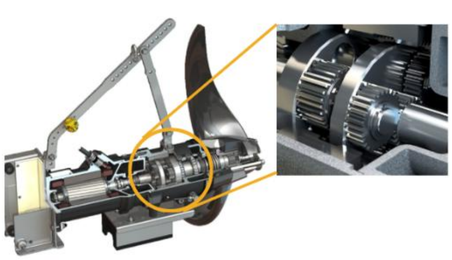
Propeller Design & Materials: The propeller is the key component that converts motor power into fluid motion, and its design and material selection have a major impact on mixer energy efficiency. A well-designed, lightweight propeller reduces the horsepower needed for mixing, improves the thrust-to-power ratio, and lowers overall energy consumption.

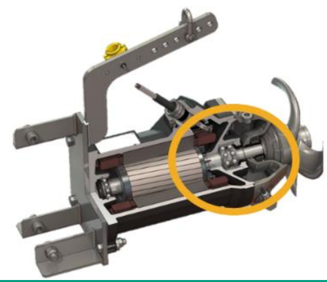
- **Design:**
  - **Blade shape:** Sweptback or hydrofoil-style blades reduce turbulence and drag, allowing smoother fluid motion with less wasted energy.

    - **Diameter:** Large-diameter propellers move more liquid per revolution, often requiring lower rotational speed and less motor power to achieve the same thrust compared to small-diameter propellers.
    - **Surface profile:** Hydrodynamic blade profiles, like airplane wings, create pressure differences that "lift" fluid more efficiently, improving thrust-to-power ratio.
- **Materials:**
    - **Polyurethane (PUR) versus cut-and-welded stainless steel:** Polyurethane propellers are lighter, requiring less torque and motor output to rotate compared to cut-and-welded stainless steel propellers of the same size. However, in recent years, cast stainless steel propellers are coming on to the market combining the efficiency benefits of the molded PUR with the durability and robustness of stainless steel. The cast stainless steel propeller matches the energy demand of PUR designs while offering superior long-term strength and resistance to abrasion, scaling, and fouling.
    - **Durability versus efficiency:** While cut-and-welded stainless steel is robust, its higher mass and inefficient blade shape increase energy demand. Polyurethane provides an efficiency advantage without sacrificing performance in most wastewater applications.
    - **Wear resistance:** Material choice affects long-term efficiency. Propellers designed to resist abrasion, scaling, and fouling preserve their smooth surface and hydrodynamic properties, reducing drag and energy use while sustaining thrust.

Gear-Drive Systems: The gear-drive system connects the motor to the propeller and determines how efficiently motor power is transferred to the propeller and converted into thrust. The choice between direct-drive and gear-drive designs has a major impact on both efficiency and lifecycle costs.

- **Speed reduction:**
    - Motors operate efficiently at higher speeds, but larger diameter propellers mix liquid more effectively at lower speeds.
    - A planetary gear-drive creates an optimal lower propeller speed with a high-speed motor without forcing the use of oversized or high-pole, slow-speed, direct-drive motors. This allows the gear-drive mixer to deliver the required thrust with less wasted energy and enables use of smaller power motors for the same thrust output. Direct-drive mixers may require 14-16 poles, which are expensive to build, repair, and rewind and often result in higher energy consupmtion if the propeller design isn't perfectly matched to the process.
- **Torque Transfer:**
    - Gears multiply torque, enabling the propeller to move large volumes at lower horsepower.
    - Efficient torque transfer means the motor does not have to work as hard, improving the thrust-to-power ratio.
- **Maintenance and Longevity:**
    - A slower turning propeller speed results in less wear on the mixer's bearings and seals, which means longer life, much greater reliability, and lower maintenance costs.
    - A properly designed gear system reduces mechanical stress on the motor and propeller, improving reliability.
    - Less wear means consistent performance over time, preventing energy losses due to degradation.

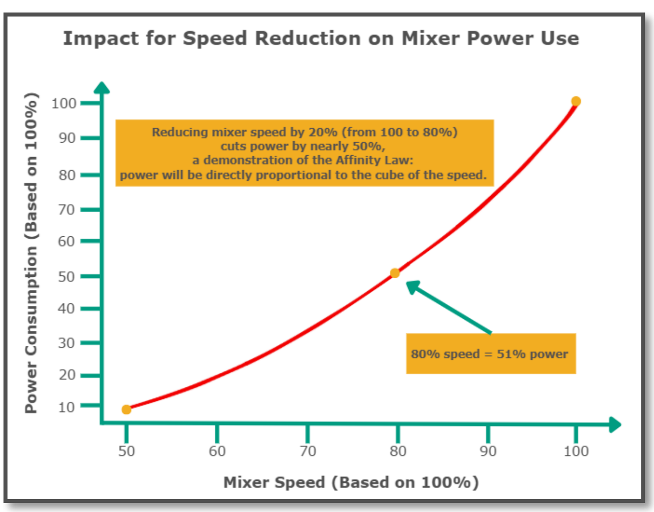




Planetary Gear Drive | **Direct Gear Drive**

Motor Efficiency & Controls: The motor is the driver of a submersible mixer, and its efficiency directly affects how much electrical energy is converted into mechanical power. In addition, control systems determine how much of that power is applied in real-world operations.

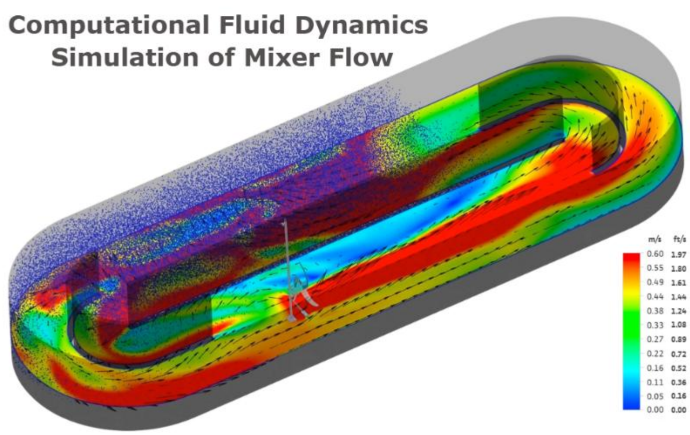
- **Efficiency:**
  - **IE motor classes:** Motors are rated by international efficiency classes (IE1-IE4). High-efficiency motors (IE3 or IE4) reduce electrical losses and deliver more usable power for the same energy input.
  - **Operating range:** Motors perform best near their rated load. Undersized or oversized motors waste energy, either by overheating or running inefficiently at partial load.
  - **Lifecycle value:** A premium-efficiency motor may cost more upfront but reduces electricity consumption over the life of the mixer, which is often the largest cost factor.
- **Controls:**
  - **Fixed-speed operation:** Without controls, a motor always runs at full speed, even if mixing demand is lower, which can lead to uncecessary energy usage.
  - **Variable Frequency Drives (VFDs):** Allows operators to adjust mixer speed to match real-time processing needs. VFDs enable mixers to operate only as needed, cutting energy use during low-load conditions. Lowering speed reduces energy consuption significantly, as power draw decreases with the cube of speed (affinity laws). While VFDs improve efficiency, they add capital cost, require space, and can increase maintenance demands. Selecting and optimizing the gear-drive mixer for the required mixing energy minimizes the need for a VFD and reduces capital cost.



Installation and Hydraulics

Energy efficiency depends not only on the mixer itself, but also on how it interacts with the basin environment. Even the most efficient mixer can waste energy if not correctly installed or if tank hydraulics are unfavorable. Proper positioning and system design are cricital to ensuring all of the mixer's thrust is used effectively, maximizing the mixing effect with the minimum energy input.

- **Placement:**
  - **Depth and angle**: Mounting too shallow or at the wrong angle can cause short circuiting, surface vortices, or dead zones. Correct positioning ensures solids remain suspended without requiring extra energy.
  - **Coverage:** Multiple mixers may be needed in larger basins, but strategic placement prevents overmixing and reduces overall power demand.
- **Hydraulics:**
  - **Tank shape and size:** Corners, walls, and irregular geometry disrupt flow, often requiring more thrust to achieve proper mixing. Smooth, rounded basins are more energy-efficient.
  - **Obstructions:** Pipes, aeration grids, or equipment inside the tank can block flow paths, forcing mixers to work harder.
  - **Process variablity:** Biological processes or influent changes alter flow dynamics. A properly adapted setup can decrease energy use by 5 to 10 percent.



Measuring Efficiency

While motor efficiency is important, the industry standard for evaluating submersible mixer efficiency is set by **ISO 21630** and is measured by the thrust-to-power-ratio (N/kW). This metric measures how much thrust, or mixing force, a mixer generates per unit of power consumed.

Mixer Theory Equation

$$P_{RW} = Ne * \rho * n^3 * d_{prop}^5$$

$$\text{Or } P_{RW} \approx n^3 * d_{prop}^5$$

P_{RW} = mixing power
Ne = Power factor depends on the tank geometry
ρ = Density
n = Propeller speed
d_{prop} = Propeller diameter

Submersible mixers operate in complex fluid dynamics where motor class alone cannot predict performance. Unlike IE motor classes, which only assess motor conversion efficiency, the thrust-to-power ratio evaluates the entire system's performance, including the motor, propeller, gearing, and interaction with the liquid.

Unlike pumps, which are measured by **head and pressure**, mixers are measured by **thrust (N)**. Because of this fundamental difference, the **Hydraulic Institute's** pump standard does not apply. Instead, ISO 21630 establishes global testing procedures for measuring axial thrust and power consumption, ensuring accurate, apples-to-apples comparisons across mixer designs and manufacturers.

Best Practices for Energy Savings

Energy efficiency in submersible mixers is not just about reducing electricity consumption – it improves reliablity, lowers lifecycle costs, and supports sustainability goals. By following recongized standards and applying best practices for energy savings, operators can achieve long-term savings while ensuring effective mixing performance:

- Select mixers based on the thrust-to-power ratio and mixing power application need, not just motor rated power and motor efficiency.
- When appropriate for the application, use high-efficiency motors and optimized gear drives.
- Employ VFDs to match energy use with demand when beneficial.
- Perform regular maintenance (cleaning propellers, checking bearings, inspecting seals, change lubricants) to prevent efficiency losses.
- Evaluate system-wide hydraulics, sometimes relocating a mixer can cut power needs significantly.

Wilo is Your Solutions Provider

Wilo USA, headquartered in Cedarburg, WI, is a global leader in pumps and mixing systems for **building services**, **water management**, and the **industry**. With a focus on intelligent, energy-efficient, and eco-friendly solutions, Wilo helps municipalities and industries reduce operating costs while improving sustainability.

Wilo's best-in-class **submersible mixers** are engineered for maximum energy efficiency, reliability, and long service life. Designed and tested in line with international standards, Wilo's mixers deliver thrust-to-power ratios ensuring optimal mixing with minimal energy use without the costly addition of VFDs. Wilo's portfolio includes the Wilo-Flumen OPTI-TR and Wilo-Flumen EXCEL-TRE product lines and the **Wilo-EMU TR(E) 216-326** lines.

Whether you are sizing a mixer for new construction or upgrading for efficiency gains, Wilo provides the expertise, products, and services to deliver sustainable mixing solutions that lower energy use and total cost of ownership.

For more information regarding Wilo's submersible mixers, visit the **Wilo USA website** or explore the **Wilo Product Guide**.

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