



# WHITEPAPER

## Motors with Flat Efficiency Curves:

How PCB Stator Technology Maintains Peak Performance Across Load Conditions

In electric motor design, efficiency is often highest at a single load point and quickly drops off as conditions change. This leads many OEMs to build and stock multiple motor SKUs to cover a wide range of operating scenarios. But that paradigm is shifting. Thanks to PCB Stator motors and ECM's PrintStator software, engineers can now build motors with flat efficiency curves that maintain high performance across a broader range of torque and speed.

This isn't just a technical advantage. It's a complete rethink of how motors are designed, deployed, and scaled across industries like HVAC and pumps.

PCB Stator motors, designed using ECM's PrintStator platform, break that pattern. By combining a coreless architecture with precision-designed copper traces, these motors maintain high efficiency across a broad operating range – not just at peak load.

### THE PROBLEM WITH EFFICIENCY PEAKS

In radial flux motors with iron cores, efficiency tends to peak at a specific operating point and drop off steeply at lower speeds or varying loads. This is due to increased core losses and magnetic hysteresis. As a result, HVAC and pump systems often experience higher energy consumption, excess heat, and reduced performance during off-peak operation.

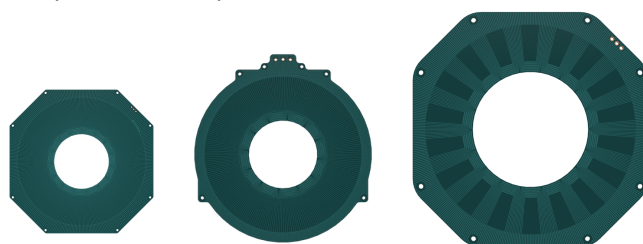
This not only affects energy efficiency but can also increase total cost of ownership, as systems must be over-engineered or carefully tuned around the motor's limitations, reducing flexibility in dynamic environments.

### WHAT IS A FLAT EFFICIENCY CURVE?

A "flat efficiency curve" means that a motor maintains consistently high efficiency across a wide range of operating conditions. Instead of peaking at one torque point and rapidly declining, the motor delivers strong performance throughout its working range. This leads to better energy usage, less heat generation, and more design flexibility.

#### Why Do PCB Stator Motors Deliver Flatter Efficiency Curves?

- **Coreless Design Eliminates Magnetic Losses** - No iron core means no hysteresis loss and minimal eddy current losses. PCB stator motors avoid the sharp efficiency drop-off seen in traditional motors.
- **Precision Etched Copper Traces** - Instead of wound coils, copper traces are patterned on a PCB for consistent and repeatable geometry. This design flexibility allows engineers to optimize conductor width, thickness, and routing to match the power and size demands of the application. Notably, copper traces can be widened at end turns where resistance is typically highest, reducing localized heating and overall, I<sup>2</sup>R losses. This intelligent geometry is one reason PCB stator motors maintain high efficiency across a wide range of load points and speeds.



- **Flat Efficiency Curves, Tuned for the Application** - With PrintStator, engineers can design custom motors around multiple operating points, setting efficiency targets at each one to achieve a flat, high-efficiency torque-speed curve. Motors are tailored to the system's load profile from the start, not retrofitted to match it.
- **Thermal and Control Optimization** - ECM incorporates inactive copper traces specifically designed to draw heat away from critical areas. This built-in thermal pathway reduces hot spots and helps the motor maintain consistent performance under varying load and temperature conditions. When paired with integrated drive electronics, this approach ensures stable, high-efficiency operation across the full duty cycle.

## THE REAL-WORLD IMPACT OF FLATTER EFFICIENCY CURVES

What does this mean in practice? It enables ECM partners to streamline their motor lineups while delivering better performance.

ECM has helped multiple partners streamline their supply chains by reducing the number of unique motors needed across product lines. Each motor is optimized for multiple load points, allowing for broader use with fewer designs.

### Example: North American Pump Manufacturer

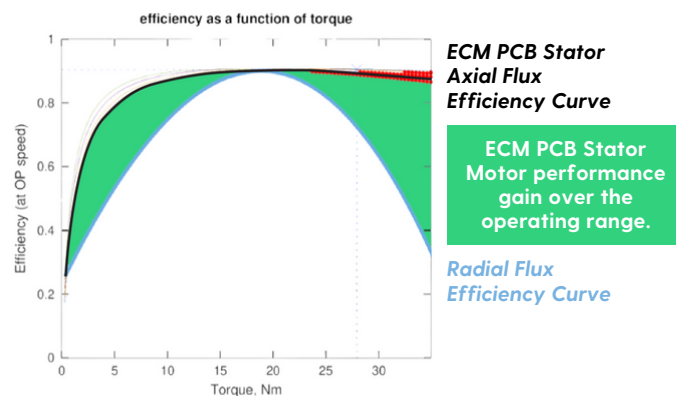
- ECM enabled a partner to vertically integrate motor production at their facility in Europe, supporting the development of a new line of ultra-thin, IE5-efficient industrial pumps.
- The number of motor SKUs was reduced from 12 to just 4, all from a single motor technology.
- Motor power ranged from 200W to 1.5kW, with each unit optimized for up to 12 distinct operating points.
- Designs were tailored to environmental temperature ranges and application-specific torque-speed demands.

- Common case designs were used across two of the four motor SKUs to further simplify manufacturing and supply chain management.
- The partner is now working with ECM to integrate PCB Stator motors into additional product lines beyond industrial pumps.

In data center cooling systems, ECM motors achieved greater than 90% efficiency not only at peak load, but also across low-speed, off-peak cycles, saving energy without compromising control.

## WHAT THE DATA SHOWS

The image below illustrates the difference. The ECM PCB Stator motor maintains high efficiency (above 85%) across a broad torque range, while a traditional radial flux motor peaks in a narrow band and drops off steeply. The green area represents the efficiency advantage that ECM motors deliver in real-world conditions.



ECM PCB STATOR EFFICIENCY CURVE VS RADIAL FLUX CURVE

## READY TO OPTIMIZE YOUR MOTOR LINEUP?

Motors designed with ECM's PrintStator platform deliver consistently high efficiency under real-world operating conditions. This is made possible by the coreless design, custom trace geometry, and software-led optimization that traditional motor designs can't replicate.

For OEMs building HVAC systems, fluid handling products, or robotic platforms, this means less waste, better performance, and more control.

**Start Your Motor Project Today.**