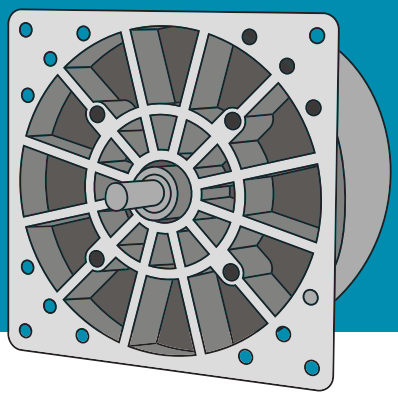
Technology Early Deployment

C-Motive

Efficient High-Torque Electric Motor

using Electrostatics Instead of Electromagnetics.



Since Michael Faraday's invention of the first electric motor to use electromagnetic forces to create motion in 1821, virtually all large-scale motors have relied on electromagnetics—the creation of magnetic fields from currents—to generate torque. Even though the very first electric motor invented by Benjamin Franklin in 1748 utilized electrostatics—the creation of electric fields from voltage—to generate torque, electromagnetic designs have dominated the engineering design of motors over the last century.

C-Motive is a startup company out of the University of Wisconsin-Madison, that has developed a disruptive motor technology based on electrostatics. The C-Motive electrostatic capacitive motor platform offers high torque density and has the potential to scale to MW size, without the need for magnets or rare-earth metals, using a fraction of the copper required for a conventional motor.

TECHNOLOGY BENEFITS

95%
EFFICIENCY
at low speed, eliminating gearboxes.

MODULAR DESIGN
scalable for MW power levels.

NO RELIANCE
on rare-earth metals.

10x
TORQUE DENSITY
for EVs, drones, and heavy hybrids.

NO HEAT GENERATION
from electric fields.

LOW OR NO MAINTENANCE
for consistent performance.

DATA SENSING
for temperature monitoring & advanced diagnostics.

Disclaimer: C-Motive Technologies' motor technology was chosen for TED because it supports **California's clean energy goals** for energy efficiency, reduced GHG emissions and demand flexibility. This document does not constitute or imply endorsement, recommendation, or favoring by EPRI or SCE of the product or company described herein. This publication is funded and administered by Southern California Edison's Emerging Technologies Program.

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C-Motive technology key components

Traditionally, electric motors have relied on the principles of electromagnetism to transfer electrical energy to mechanical energy. Electric motors have used these principles to create a moving magnetic field by the current-carrying coils in the stator to create motion in the rotors. Similarly, the electrostatic principles can be used to translate electrical power to mechanical power. C-Motive has tapped into Maxwell's law of electric fields to create a capacitive power transfer mechanism and have demonstrated proof-of-concept for this technology which could have wide application.

The innovation of this concept lies in the capacitive power coupling between non-touching plates on the stator and rotor. A static high voltage field is applied to the rotor and a variable frequency voltage source is applied to the stator, creating an electric field between rotor and stator plates that applies mechanical torque to the rotor. The stator plates can be thought of as analogous to stator windings in an induction motor, while the rotor plates are like a rotor shaft and windings. Like brushless dc motors, this design avoids the use of high-maintenance contact carbon brushes and slip rings but does so without the use of permanent magnets made of rare earth metals. Currently, C-Motive's technology can transfer power as low as 10W to beyond 20kW through its rotary capacitance.

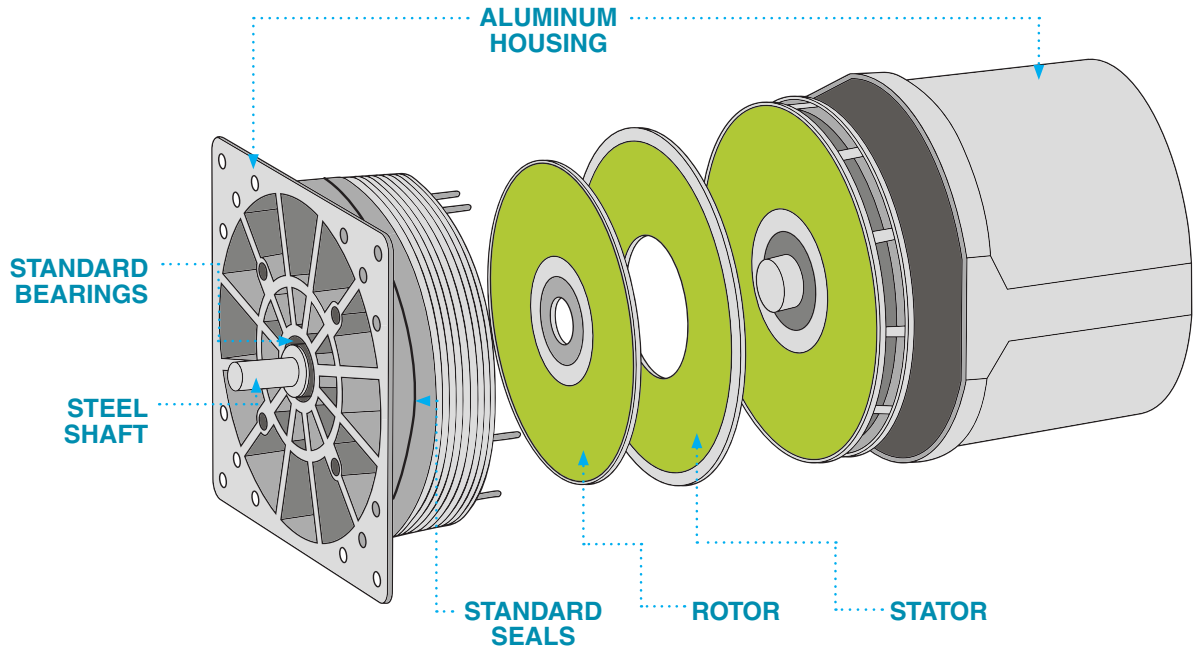
Currently C-Motive has developed two product platforms called CoolTorq 10 and CoolTorq 20 .

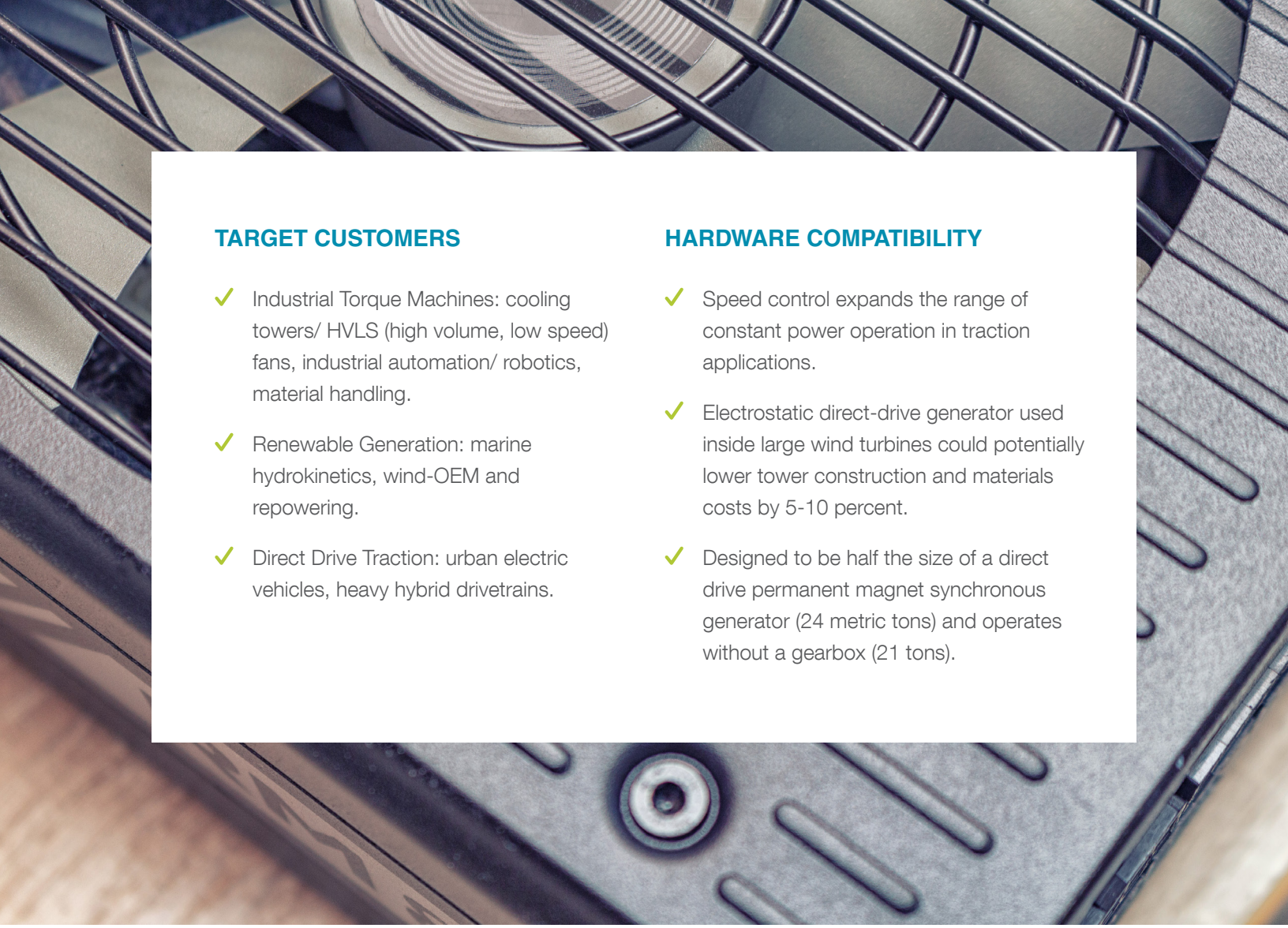
COOLTORQ 10 SPECIFICATIONS

Diameter	10"
Speed	<500 rpm
Power	1.5+kW
Torque	<30+Nm

COOLTORQ 20 SPECIFICATIONS

Diameter	20"
Speed	<500 rpm
Power	<20kW
Torque	<400Nm





TARGET CUSTOMERS

- ✓ Industrial Torque Machines: cooling towers/ HVLS (high volume, low speed) fans, industrial automation/ robotics, material handling.
- ✓ Renewable Generation: marine hydrokinetics, wind-OEM and repowering.
- ✓ Direct Drive Traction: urban electric vehicles, heavy hybrid drivetrains.

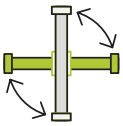
HARDWARE COMPATIBILITY

- ✓ Speed control expands the range of constant power operation in traction applications.
- ✓ Electrostatic direct-drive generator used inside large wind turbines could potentially lower tower construction and materials costs by 5-10 percent.
- ✓ Designed to be half the size of a direct drive permanent magnet synchronous generator (24 metric tons) and operates without a gearbox (21 tons).

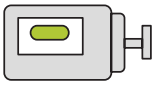
SYSTEM FEATURES

GREATER TORQUE DENSITY
> 10 TIMES

HIGH EFFICIENCY > 95%



FLEXIBLE SHAFT ORIENTATION



DIRECT DRIVE

TEMPERATURE STABILITY

California's decarbonization challenge

California's executive order B-55-18 mandates that the state achieve carbon neutrality by 2045. Additional legislation supports this goal through multiple strategies that include double energy savings by 2030 (SB 350), increased demand flexibility (19-OIR-01), advanced energy storage and 100 percent of all retail electricity from renewable energy (SB 100). Applying these strategies to new construction and upgrades to existing buildings provides a path to achieving carbon neutrality but also comes with a new set of challenges:

1.

New technologies for buildings

must support most or all of the desired outcomes for California.

2.

Testing, compliance & standards

including utility participation and enabled workforce.

3.

Establishing trust

that replacement of old systems will meet/exceed performance expectations.

C-MOTIVE SUPPORTS CALIFORNIA'S DECARBONIZATION GOALS

HIGH PERFORMANCE

Improves motor efficiency across industries.

HIGH EFFICIENCY

Eliminates gearboxes, thermal cooling, and excess noise.

DEMAND REDUCTION

Supports electrification applications.

Addressing market barriers to adoption of electrostatic motors

C-Motive's electrostatic machine topology is a novel concept that offers a unique and desirable value proposition at the performance, economic and sustainability levels.

BARRIERS STILL EXIST IN SEVERAL AREAS:

Barriers

FOR EXPANSION

- ✓ Field demonstration data.
- ✓ Utility specific use cases.
- ✓ Lack of brand awareness.

TO SCALE

- ✓ Manufacturing supply chain.
- ✓ Workforce training.
- ✓ Customer adoption.
- ✓ Development of distribution and service relationships.

CREATING A PATH TO COMMERCIALIZATION THROUGH THE FOLLOWING ACTIVITIES:

Opportunities

UTILIZE LEVERAGE POINTS

- ✓ Feasibility project for U.S. Navy (under NSF STTR 2019).
- ✓ Collaboration with EPRI.
- ✓ Re-using established motor components and engineering design.

REALIZE COMPANY GOALS

- ✓ Field demonstrations with customers in Northeast and Southwest.
- ✓ Expand manufacturing capabilities.
- ✓ Expand interest across utilities and industry professionals.

Market readiness

4

TECHNOLOGY READINESS LEVEL SCORE

- Proof-of-concept design lab tested.
- Pre-commercial stage of development.

2-3

YEAR TO MARKET

- After field demonstrations, TRL expected to improve.
- Commercial availability to improve with financing options.

4

MANUFACTURER READINESS LEVEL SCORE

- Identifying scale-up manufacturing.

1

KEY OUTCOME

- It is estimated that the TRL for C-Motive technology could increase to 6 or 7 in certain applications once field testing is completed to validate real-world performance.

Supporting utility goals for decarbonization

1.

Energy savings

Reduces energy consumption.

2.

Decarbonization

Promotes electrification.

3.

C&S alignment

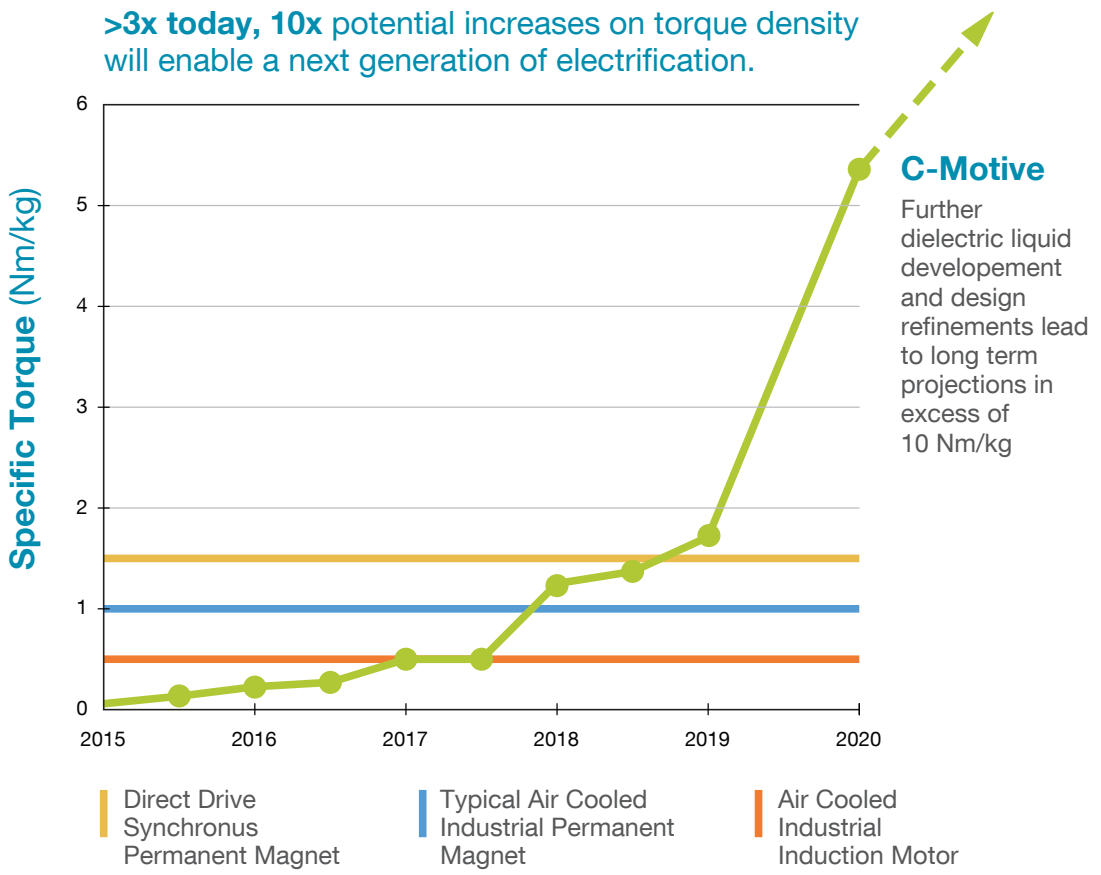
Supports innovation in generation, transportation, and load devices.

4.

Demand flexibility

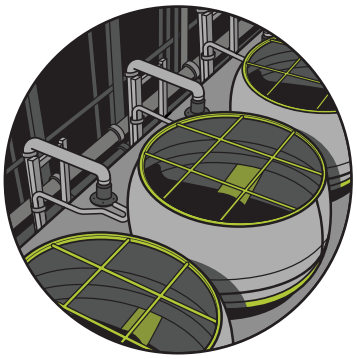
Potential to improve motor flexibility through integrated drive.

C-Motive's technology has a 10x potential for increasing torque density without increasing energy use, enabling the next generation of electrification across industrial applications.

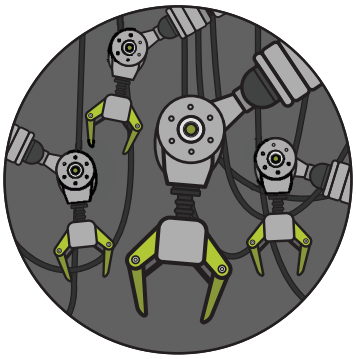


INDUSTRIAL TORQUE MACHINES

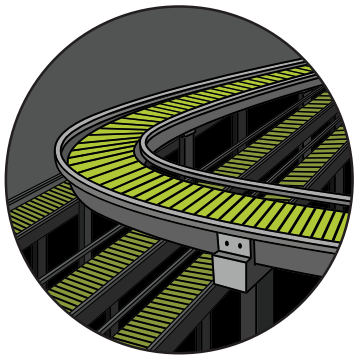
CoolTorq platform is the foundation for a wide range of applications but is currently being tested across cooling towers, HVLS fans, industrial automation and robotics and material handling applications.



COOLING TOWERS / HVLS FANS



INDUSTRIAL AUTOMATION / ROBOTICS



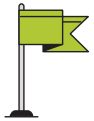
MATERIAL HANDLING

C-Motive Utility Opportunity Assessment

TECHNOLOGY CATEGORY

Motors and Drives

Process Loads and Appliances



ETP PRIORITIES

ENERGY SAVINGS

Reduces energy consumption.

DECARBONIZATION

Promotes electrification.

C & S ALIGNMENT

Supports innovation in generation, transportation, and load devices.

DEMAND FLEXIBILITY

Potential to improve motor flexibility through integrated drive.

KNOWLEDGE INDEXES

TECHNICAL PERFORMANCE

High

MARKET KNOWLEDGE

Medium

PROGRAM INTERVENTION

Low

UTILITY VALUE

- $100B+ global market size.
- Beachhead: $8-10B
- SAM: $15B
- TAM: $50B

OPPORTUNITIES

CRITICAL ETP ACTIONS

- Socialize within SCE.
- Socialize with other IOUs.
- Field test in CA.

LEVERAGE POINTS

- NSF grant.
- EPRI Motors and Drives Team.

GAPS TO FILL

- 3rd party testing.
- Utility specific use-case.

MARKET SIZE

- Innovative Motor and Drive technology for incentives.
- Combines electrification with decarbonization goals.

BARRIERS

IN-PROGRESS

- Field demonstration.
- Utility specific cases.
- Lack of brand awareness.

UPCOMING

- Manufacturing supply chain.
- Development of distribution & service relationships.
- Customer adoption.

SOLUTION

- Build brand awareness.

NEXT STEPS

COMPANY

1. Field demonstrations.
2. Expanded manufacturing capability.
3. Utility-specific cost-benefit analysis.

UTILITY

1. Field demo results.
2. Value proposition and business use case.

OTHER

1. EPRI M&V testing and/or grant collaborator.
2. Partnerships with OEMs.

ted

TED is a process where innovative technologies are selected for assessment and review based on the technology application, team strength, and alignment with the Technology Priority Maps, to fulfill the California decarbonization challenge.

FOR MORE INFORMATION

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