How Clean is Clean Energy?

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Abstract
Electric vehicles and clean energy production have become increasingly popular, making electric motors more in demand than ever before. Currently, the majority of electric motors use magnets created with rare earth resources such as Neodymium and Dysprosium. The supply chain for these materials is fragile, and they are not being produced in sufficient quantities to meet the needs of clean energy initiatives. With this in mind, we wanted to address the issues surrounding magnets in motors. Our objective was to determine if an environmentally friendly magnet composed of aluminum, gallium, and manganese could power an electric motor. We investigated the fundamentals of brushed DC motors, designing and we prototyped a DC brushed motor, and ultimately created a simple, modular final product.
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Background
- Rare earth magnets are crucial components in clean energy devices such as electric motors
- Demand for Rare Earth Elements exceeds supply, both now and in the future
- This will make clean energy devices non-economical
- We need magnetic materials which have reduced or no Rare Earth Element content

Objectives
- Identify potential problems caused by rising technological demand and the shift towards “clean energy” devices
- Build a rudimentary rare-earth free electric motor to further understand potential alternatives/solutions to these problems
- Investigate novel magnetic materials which could replace the Rare Earth permanent magnets in electric motors

Challenges
- The Rare Earth Element Magnets (3.5 kg) in a single EV motor have as their mining waste [2]:
  - 7000 kg of acidic clay (~8 cubic yards - driveway sized mound)
  - 70 gallons of acid water (~2 bathtubs)
  - 3.5 kg of radioactive residue

Projected Supply vs demand of rare earth elements, assuming Paris climate accord targets are met [1]

Electromagnets

Ampere’s Circuital Law
\[ \nabla \times B = \mu_0 J \]

Circulating Magnetic Field
Electric Current

This can work backwards - a circulating electric current can create a linear magnetic field.
An iron core enhances this field.

Permanent Magnet Stator

Motor Architecture

Magnetic Fields Gets up to Speed, March 13, 2020, Physics 13, 37

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Pollution from neodymium mining in China [3]