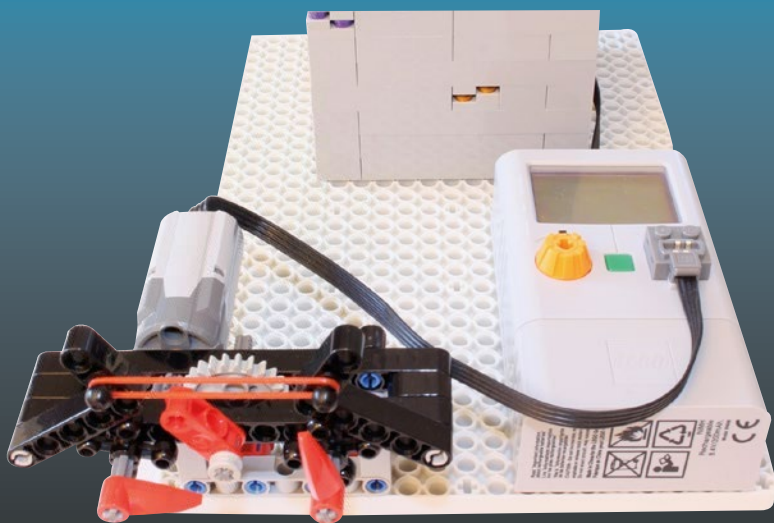




LEGO Wind Energy



Green Energy Projects with
Mindstorms EV3

—
Grady Koch
Elias Koch

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LEGO Wind Energy: Green Energy Projects with Mindstorms EV3

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For Melissa

Table of Contents

About the Authors.....	ix
About the Technical Reviewer	xi
Introduction	xiii
 Chapter 1: The Generator.....	 1
Generator Basics.....	1
Putting a Generator to Use	6
Non-LEGO Generators	12
Generator Wire Connections	15
Summary.....	16
 Chapter 2: The Gearbox	 17
LEGO Gears	17
Gearing Up	19
Compound Gears.....	23
Summary.....	26
 Chapter 3: The Vertical-Axis Turbine	 29
Catching the Wind	29
Generator Mount	31
Gearbox Frame.....	36
Joining the Generator and Gearbox	46
The Rotor.....	47
Final Assembly	49

TABLE OF CONTENTS

Mount for KidWind Generator.....51

Summary.....55

Chapter 4: Airfoil Blades.....57

 The Airfoil57

 Wrapping in Duct Tape62

 Design Ideas64

 Summary.....65

Chapter 5: The Horizontal-Axis Turbine.....67

 The Generator/Gearbox68

 Rotor and Blade Attachment73

 Final Assembly76

 Mount for KidWind Generator.....77

 Summary.....83

Chapter 6: Measuring Performance.....85

 Test Setup85

 LEGO-based Meter89

 Assessing Turbine Performance.....90

 Relationship Between Power and Energy91

 Automated Energy Measurement.....93

 Summary.....95

Chapter 7: Steering into the Wind.....97

 The Steering Vane97

 Final Assembly102

 Outdoor Testing103

 Summary.....107

Chapter 8: Powering Things	109
LEDs Powered by Wind	109
Charging a Battery	113
Summary.....	115
Chapter 9: A Dual-Rotor Turbine.....	117
Counter-Rotating Blades	117
Electrical Connection	122
Summary.....	124
Chapter 10: A Pneumatic Generator	125
Design of the Pneumatic Turbine	125
Pneumatic Connection	131
Summary.....	132
Appendix: Parts Lists.....	133
Index.....	145

About the Authors

Grady Koch emphasizes building things from LEGO that can be applied to practical use in science, engineering, or security. He is the author of *LEGO Optics: Projects in Optical and Laser Science with LEGO*, *High-Tech LEGO: Projects in Science, Engineering, and Spycraft with Technic and Mindstorms EV3*, and *Secrets of Eli's LEGO Collection*. He also writes for and runs hightechlego.com, which features various LEGO technology projects. His day job since 1987 has been as a research engineer with the NASA Langley Research Center. There, he works with technology for remote sensing atmospheric phenomena. He holds a PhD in electrical engineering and holds three patents in the field of wind measurements with lidar.

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Introduction

Electrical power is so much the foundation of today's society that we've felt the need to produce power from scratch, even if it's only a little. We could purchase a diesel generator or solar-power array, but we find the idea unsatisfying since this would not really help us to understand or build a capability ourselves. Building a machine is to truly understand the machine—hence our fascination over the years with LEGO. LEGO makes building machines easy. And so our journey began to generate electricity from LEGO parts.

Wind has been used as a power source for millennia, perhaps because it's easy to harness with relatively simple technology. Sailboats are known to have been in use for at least 5,000 years. The earliest known use of wind energy to turn a wheel is from Heron of Alexandria in the first century A.D., who used wind to power a musical organ. In the seventh century, windmills were invented to grind grain and pump water, and such use flourished throughout the world. In 1887, the first wind turbine for generating electricity was built in Scotland by James Blyth. Today, wind power provides about 4 percent of the world's generated electricity.

Now, with this book, people can join in on the wind-energy adventure using their LEGO collection. We don't mean LEGO models that look like miniature wind turbines. This book shows functioning wind turbines that generate electricity. It's not much electricity, and if a person's interest is in micro-scale wind turbines for practical use, there are many such pre-made devices available on the market. Rather, this book is for people who want to learn how turbines work, are participating in a wind power design competition, are generally interested in alternative energy, or are LEGO fans looking for a new direction. LEGO does make a wind-power

INTRODUCTION

kit in set 9688 Renewable Energy Add-On, but it's a fairly simple kit that involves pressing together a few elements, including pre-made turbine blades. We found this set rather lacking for a person seeking to explore and understand how turbines work and how to optimize performance. The LEGO system's great variety offers so much more in design possibility.

One reason to look into homemade wind turbines is that many students take part in wind turbine design competitions, such as the KidWind Challenge, Collegiate Wind Competition, and locally organized contests. The use of LEGO is permissible by the rules of these competitions, but seems not to be well exploited. In this book, examples are given that fit within the KidWind Challenge, including adherence to rules of the competition, such as that a specific generator be used.

Wind turbines are perhaps so popular for educational competitions because their construction touches on many aspects of science and engineering: aerodynamics, mechanics, structures, electricity, electronics, and meteorology. There's much that can be learned by building a wind turbine, but, on the other hand, the complexity can make it difficult to know where to start. We wrote this book to give such a start, with the many aspects of the turbine addressed with practical examples. We give specific design instructions for turbine construction, but also provide suggestions and background science to go in new directions. Our hope is to encourage people to create their own designs. Considering that kids of middle-school age may be interested in this topic, we've written this book so that such kids can understand the material with the help of an adult coach. High school students can likely work through the material on their own.

LEGO parts come in a bewildering variety, so to identify parts we use a convention of part number and description. This part number can be typed into online marketplaces, such as bricklink.com. For example, the iconic LEGO brick would be identified as

#3001 2x4 Brick

Assembly diagrams are used throughout the book, made with the Studio utility from bricklink.com. Parts are identified in the assembly diagram, as well as in parts lists in the appendix. Color choice is, of course, up to the builder's taste. We tend to favor black and grey color schemes, but there is nothing wrong with choosing festive colors or even whatever color is on hand.

As when building any machinery, consideration should be given to safety. The electrical power generated by the turbine designs in this book is rather low and is not likely to present a hazard. Rather, the most hazardous aspect of this book's material is from parts coming loose and flying through the air, creating an eye hazard. We've had many instances of turbine blades breaking loose during high-speed rotation. These blades are not heavy enough to hurt, except for the possibility of eye injury. So, it's vitally important to wear safety glasses during the experiments described in this book.

CHAPTER 1

The Generator

A generator is the foundation for electrical power generation, creating electrical current from rotary-motion input. Wind provides the rotary motion for a wind turbine generator. This chapter involves experimenting with generators by working with a LEGO-based design, including the construction of a hand-cranked generator that uses manual motion to spin it. In later chapters, this manual rotation will be replaced by energy from wind.

Generator Basics

Generators create electricity by spinning a coil of wire near a magnet via the principle of electromagnetic induction. The physicist Michael Faraday studied the phenomenon of induction, quantifying it in the law that bears his name. The essence of Faraday's law is that an electromotive force is generated in the coil, and that force is related to the time rate of change of the magnet's field strength. Consideration of Faraday's law indicates that to generate higher electrical power two approaches can be taken: (1) using a strong magnet, or (2) moving the wire coil quickly. Spinning the magnet is an effective way to move the wire coil quickly.

To illustrate how generators are actually built, Figure 1-1 shows a LEGO-based generator with the cover removed. In the opened generator, the edge of the disk of wire coils, called a *rotor*, and the edge of the magnet can be seen. Taking apart a generator as done here is likely to damage the device and is not recommended. We sacrificed a generator in our collection in the name of scientific advancement.



Figure 1-1. *The LEGO #71427c01 motor—or generator, in this case—is shown both with and without its cover*

Further disassembly of the generator, seen in Figure 1-2, shows more of the parts involved, including the rotor/magnet core, spinning axle, steel annulus, and electrical connections. *Brushes* are fine wires that touch the commutator to connect electrical output to end use. The hole in the steel annulus goes over the commutator assembly to shape and concentrate the magnetic field created by the magnet. The *commutator* is a segmented metal ring used to periodically reverse the electrical current direction so that direct current output results, rather than alternating current. When the motor is assembled, the brushes press up against the commutator. Figure 1-3 gives a close-up view of the rotor/magnet core. The rotor is at

the front of this view, featuring three coils of wire that spin about an axle that has a commutator on the end. Each coil of wire has two electrical connections; hence, there are six segments making up the commutator to accommodate all three coils. Electrical output is connected from the commutator by contact with the brushes seen in Figure 1-2. The magnet is a disk attached behind the rotor, with the magnet surface visible through the holes of the rotor's wire coils.

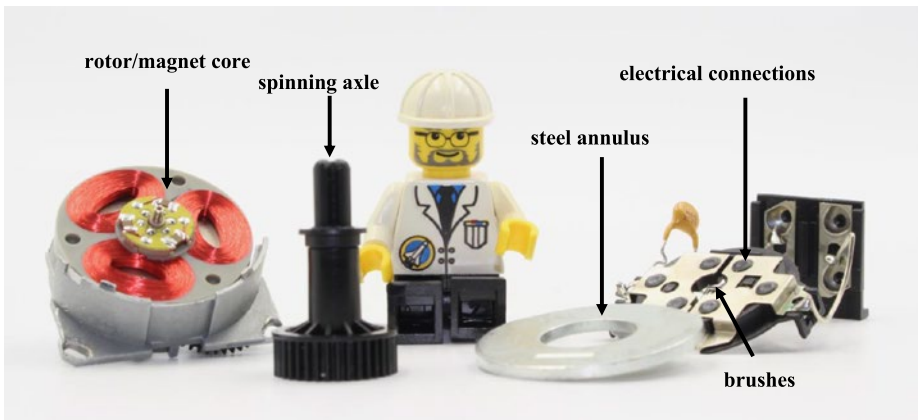


Figure 1-2. Taking apart the pieces of the #71427c01 device shows the rotor/magnet core, spinning axle, steel annulus, and electrical connections

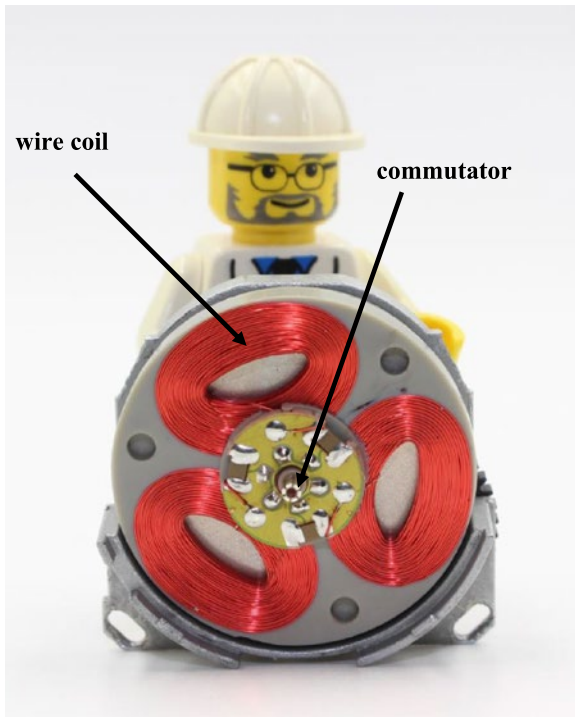


Figure 1-3. A close-up view of the rotor/magnet core shows the wire coils, commutator, and magnet

The generator shown in Figure 1-1 was not intended to be used as a generator—it's actually a motor. But motors and generators are closely related, being sort of inverses of each other. Motors create rotary motion with an electrical input, whereas a generator uses rotary motion to create electrical output. By grabbing the shaft of a motor and spinning it, an electrical current will be generated at the motor's electrical contacts. LEGO has never made a generator, but has made many types of motors. Several such LEGO motors produced over the years are shown in Figure 1-4. Only a few types of LEGO motors are suitable to be used as a generator, since most have gear systems built into their housings to make them more suitable for building vehicles or robots. This gearing can involve too high a