The background of the entire page is a light gray grid. Each grid cell contains a small, faint icon. The icons are a mix of various symbols related to technology and energy, including light bulbs, USB cables, solar panels, and circuit boards.

SOLAR PROJECT BOOK

FIRST EDITION

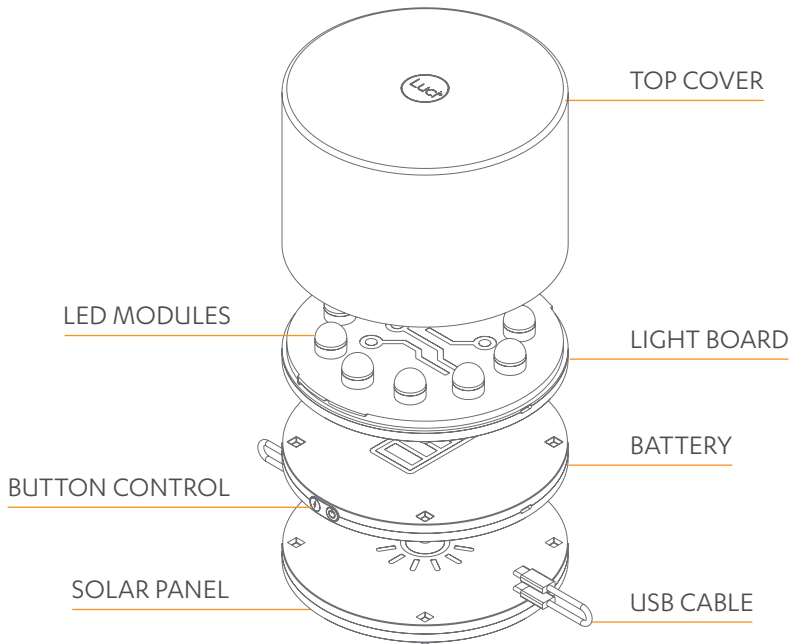
MPOWERD™





THIS BOOK BELONGS TO:

INTRODUCING
BUILD-YOUR-OWN-LUCI

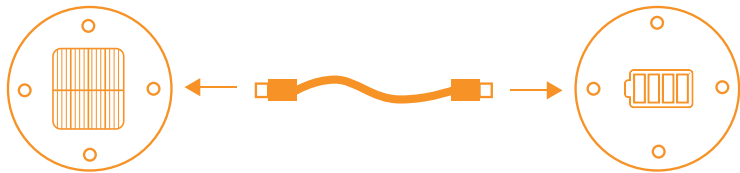


QUICKSTART


For those of you who like to just **JUMP STRAIGHT INTO THE ACTION**, this section's for you. Go ahead and get started. The mind blowing cool science stories will be here waiting for you, when you're ready.

ACTIVITY 1

1. Take 1 USB cable and connect one end to the solar panel.
2. Connect the other end of the USB cable to the battery. Press the button on the battery.

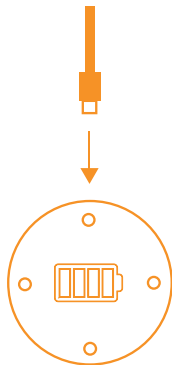


BUILD-YOUR-OWN-LUCI

3. Now find the two little buttons on the side of the battery. Press the lightning bolt button. Does the  symbol light up? If so, you're good to go! If it doesn't, check to make sure the cable is plugged in all the way.

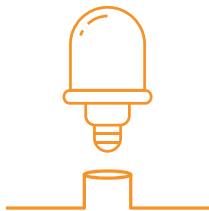
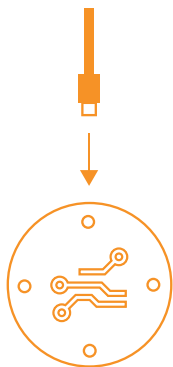


4. Take the second USB cable and connect one end to the open side of the battery.



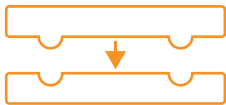
ACTIVITY 1

5. Connect the other end of the remaining cable to the light board.
6. Now go grab a handful of LEDs! Plug them into the holes on top of the light board in whatever order you want. What color combos can you come up with?

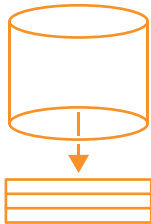


BUILD-YOUR-OWN-LUCI

7. Time to get stacking! Take the light board and rotate it clockwise over the battery so that the 4 bumps on the bottom of the light board fit into the 4 holes on top of the battery. Then do it again! Rotate your light board/battery combo to fit onto the solar panel.



8. Almost there! Take the top cover and place it over the whole thing. Now rotate it (clockwise again) until it stops moving. See that other button in the middle of your disk sandwich? Press it!



YOU NOW KNOW

HOW TO BUILD YOUR OWN LUCI!



BUT DO YOU KNOW HOW
AND WHY IT WORKS?...

"I'D PUT MY MONEY ON THE
SUN AND SOLAR ENERGY. WHAT
A SOURCE OF POWER! I HOPE
WE DON'T HAVE TO WAIT
UNTIL OIL AND COAL RUN OUT
BEFORE WE TACKLE THAT."

Thomas Edison, Inventor Extraordinaire



CHAPTER ONE

HERE COMES THE SUN

IT'S A PRETTY AWESOME TIME TO BE ALIVE. With a few taps, we can find out the answer to any question immediately, or we can talk face-to-face with someone on the other side of the world. We're making cars that can drive themselves, and even fly! Right this very minute, we have the ability to power the **ENTIRE PLANET** with clean, renewable energy. Ready or not, the future is here — and it's in your hands.

Who knows, **YOU COULD BE THE ONE** to invent the solar jetpack, 3D food printer or start offering vacations to the moon! It all starts with knowing how the tech works — but don't sweat it, we've actually been harnessing the power of the sun for **CENTURIES**. The gadget you just made is the result of the bold ideas, hard work and yep, even big mistakes of generations of people who never stopped asking "**WHAT IF?**".

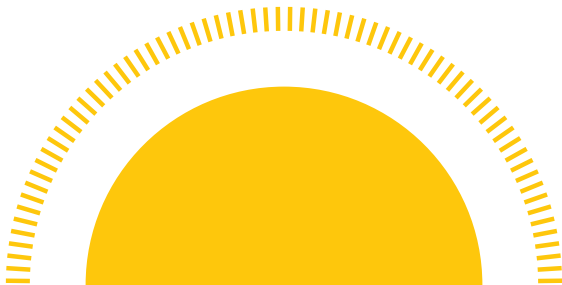
So let's get to it, and explore how we got to now.

THE SUN

You know how when it's daytime you see the big yellow sun, and at night you see the stars, and they're tiny by comparison? It took us as humans a **REALLY LONG TIME** to realize our sun was a **STAR** like any other in the sky, just a lot closer to us. A star, if you're wondering, is a super **GINORMOUS BALL OF GAS** that produces its own energy, which we see as light. It takes just 8 minutes for that light to travel 93 million miles and reach us.

So, want to see what happens when we put this gigantic speeding ball of heat to work? Take BYOL and head outside!

WEATHER ADVISORY: If it's not a bright, sunny and pleasant day, you might want to reconsider. If it's bright out but too hot or too cold, find a window where the sun is shining through and you'll be fine. If it's cloudy, stormy, or the apocalypse, stay put. We'll get through this together.



ACTIVITY 2

1. If you put your Luci light together during the Quickstart, take it apart now. Also, make sure you're in a spot where the sun is shining – this won't work if you're in the shade. We'll get into why this is important a little later.
2. Take just 1 LED and put it in the light board. Now use a USB cable to connect the solar panel, face up, to the light board. What happens?
3. Now, block the panel with your hand. What is going on here?!

DID YOU KNOW

Without a battery, you're able to turn it on and off with a simple swipe of the hand, like magic. Except it's not. It's science, and that's just as cool... it just took us several thousand years of trying different things to figure out how to do it.


ANCIENT SUN GODS

IN THE BEGINNING, the sun controlled when we were awake and when we slept – and that alone made it enormously powerful. So powerful, that in almost every part of the world, people **WORSHIPPED THE SUN** as a god.

In ancient Egypt, people made sacrifices to the sun god Ra and his daughter Sekmet before harvests and after battles.

According to the **ANCIENT AZTECS**, if they did not present the god Tonatiuh with a human sacrifice, he would refuse to make his daily journey.







The ancient Greeks believed Helios (also known as Apollo) rode his golden chariot across the sky each morning, drawn by **FOUR FIERY HORSES**.

In Hinduism, Surya's chariot has three more horses to represent the 7 colors of the rainbow.

In **CHINESE COSMOLOGY**, there were once 10 sun gods who were all brothers. One day they decided to all come out and play at once, but it got way too hot out, so a hero named Hou Yi shot 9 of them down. Only Taiyang Shen remains.



While these stories are cool (and a little scary), they don't explain why your light turns on in the sun. For that, we have to talk about light itself. The light that the sun gives off is made up of tiny packets of energy called photons - but this energy can't be used unless you know a way to collect it.

Plants know how to do it, but unfortunately plants don't have brains. We tried asking them just in case, but they're not sharing. Instead, we've come up with some pretty crazy ways over the years to harness the power of the sun.

ARCHIMEDES' DEATH RAY

In 212 B.C.E. Roman warships attacked the city of Syracuse, Sicily – home of Archimedes, a famous Greek

**MATHEMATICIAN,
PHYSICIST, ENGINEER,
INVENTOR & ASTRONOMER.**

To defend them, Archimedes constructed gigantic mirrors and placed them at specific angles to reflect sunlight. When the ships arrived, legend has it that the mirrors caused the ships to burst into flames!

Whether or not the ships actually caught fire is up for debate, but the legend inspired generations to dream of the day when we could harness the power of the sun for any purpose at all.

TAKE A LOOK AT YOUR OWN SOLAR PANEL AGAIN. IT LOOKS LIKE ONE BIG BLUE-ISH SQUARE, RIGHT?

It's actually made up of a bunch of teeny tiny units called photovoltaic cells (that's just a fancy word for converting sunlight to electricity). When a photon of light hits one of these cells, it converts the light into usable energy – but here's the thing, unlike with plants, this only works if the photon reaches the panel! We call this concept **DIRECT SUNLIGHT**.

IMPORTANCE OF DIRECT SUNLIGHT

When you put your hand in between the ray of sunshine and the solar panel, you stop the photons from hitting the cell. The same thing goes for if you're in the shade, or indoors, away from those bright patches of direct sunlight where cats love to hang out.

Here's the problem: while your solar panel is great at converting sunlight into usable energy, it doesn't have a place to store it! That's why we need batteries.

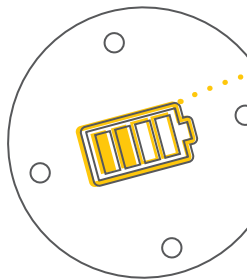
ACTIVITY 3

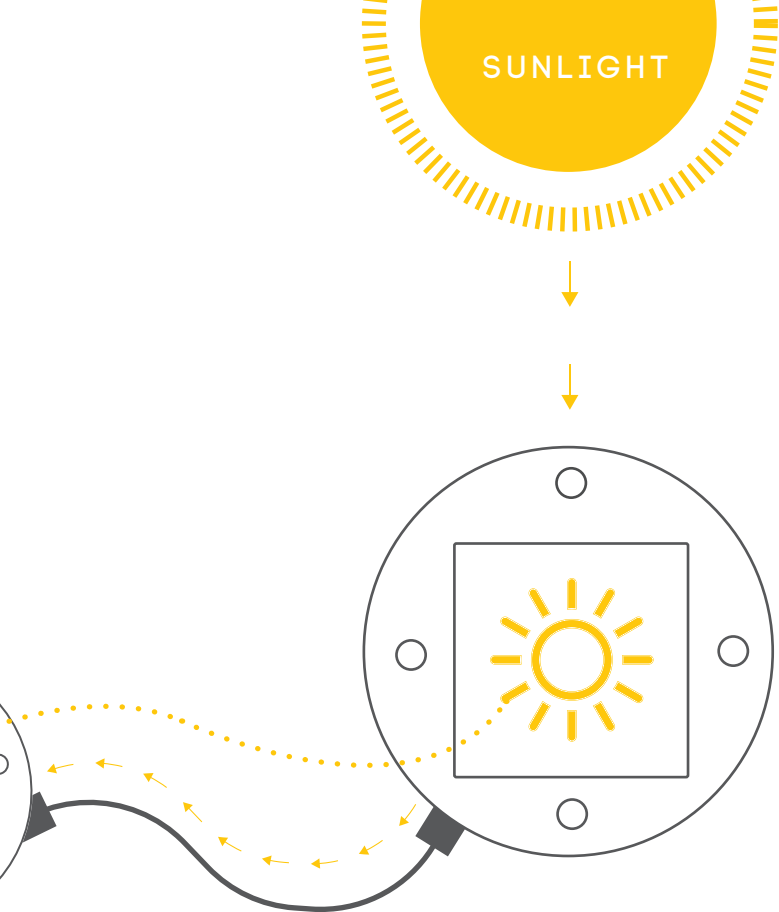
Find a safe sunny spot where nobody could trip over it, and plug your solar panel (still face up) into the battery.

CONGRATS, you just started storing energy!
But how does the solar panel actually convert sunlight into energy? What about the battery - how does that even work? It all comes down to one extremely interesting concept: electricity.

Leave your solar panel and battery to charge in the sun and head back inside (make sure it's safe and out of the way).

LET'S TALK LIGHTNING!





ELECTRICITY TRAVELS AT THE
SPEED OF LIGHT - THAT'S OVER
186,000 MILES PER SECOND!

IN ALBERTVILLE, FRANCE,

ELECTRICITY IS POWERED BY

BEAUFORT CHEESE. A SPARK

OF STATIC ELECTRICITY CAN

MEASURE UP TO 3,000 VOLTS.

ELECTRICITY CAN BE MADE FROM

WIND, WATER, THE SUN AND EVEN

ANIMAL POOP!

CHAPTER TWO

POWER UP!

ELECTRICITY

WHAT IS IT? DO YOU HAVE A GUESS? We discovered it existed long before we had any idea how it actually worked, and the truth is, we still have a **LOT** of questions about it. The good news is that we know a lot more than when we started!

ALL THE WAY BACK AROUND 585 B.C.E., even before Archimedes, another ancient Greek named Thales of Miletus decided to rub some fur over a piece of amber. **WHY? WHO KNOWS**, but he discovered that he could use that amber to attract lightweight items like feathers.

He had stumbled onto static electricity.

TRY IT YOURSELF!

HOW? Luckily it works with things a lot more common than fur, amber or feathers. Take off one of your socks and rub it really fast against a carpet. Quick, hold it up to your hair! Notice how it stands up? Now let's take things to the next level.

Put the sock back on your foot, and rub it against the carpet again, really fast like before. Now find a sibling, parent or friend and touch them. Were they startled? Blame it on static electricity.

RUB ONE OF THESE

Your skin • Your hair
Glass • Nylon • Wool

WITH ONE OF THESE

Teflon • Vinyl • Styrofoam
Polyester • Plastic Wrap

WHY DOES THIS WORK?

Some very smart people discovered different things about electricity over the years and each had their theory – but most got it hilariously wrong.

Thales thought his little rock feather combo was evidence that Amber had a soul. Nope!

**NOW STOP WHAT YOU'RE DOING
AND HEAD TO THE KITCHEN!
TAKE A LOOK AT YOUR FRIDGE.**

Ever wonder why the magnets never fall off? Pull one. Notice how the magnet seems to resist you, wanting to stay put. The closer the magnet, the stronger the pull. That's called magnetic force.

MAGNETISM AND ELECTRICITY ARE BUDDIES.

Meet William Gilbert, **ENGLISH SCIENTIST AND KID BRANIAC**. He started college at just 14 years old, and he made the same discovery back in 1600. His idea: things that are magnetic have moving fluids inside them called "humors". Definitely not.

Willy Gilly may have been way off base with explaining why magnets work, but he more than made up for it when he discovered something bigger: the earth itself is one giant magnet!

HOW CAN THAT BE? LET'S PLAY WITH SOME TO FIND OUT HOW THEY WORK.

ACTIVITY 5

1. Take the strongest magnet from your fridge. Find a whole bunch of paper clips.
2. Bring one paperclip up to the magnet. It should dangle off of it.
3. Now bring another paperclip to the chain – they should stick together. Keep adding as many paper clips as you can – see how long you can make it!
4. Finally, remove the first paper clip from the magnet. What happened to your chain?

ACTIVITY 5

It fell apart. That's because only certain metals are what we call "**PERMANENTLY MAGNETIC.**" These metals have an invisible field that extends all around them, and they have two opposite poles, north and south. The opposite ends of different magnetic materials are attracted to one another. Those that are the same push each other away. Sound familiar?

Those metals come from the earth, which has a north and south pole.

LUIGI GALVANI & DEAD FROGS

Flash forward to 1780. Italian doctor Luigi Galvani is dissecting a **DEAD FROG** with a metal scalpel when suddenly, its leg leaps straight into the air! He jumps to the conclusion that electricity comes from animals, and might even be the source of life itself.

Needless to say, he was **DEAD WRONG**, but his famous public experiments getting dead animals (and later, dead criminals) to move did catch the eye of Mary Shelley, author of Frankenstein!



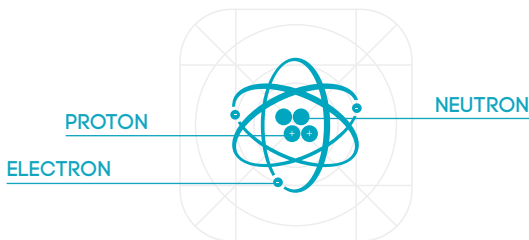
If Galvani wasn't so obsessed with his **ZOMBIE FROG**, he might have noticed that his experiment only worked when he used two different types of metals - the iron plate under the frog, and the brass hook he used to poke it.

Another Italian named **ALESSANDRO VOLTA** did notice, and in 1800 he ditched the dead frog for cardboard soaked in saltwater. He made a sandwich of the two metals (with the cardboard in between), and stacked a bunch of them on top of one another. He added conductors for positive and negative charges on both ends of this contraption, and when he connected them, **BLAM!** – the spark happened. He called his invention the battery.

SO WHAT IS ELECTRICITY?

The honest answer is that it's very, **VERY COMPLICATED**, and there's still a lot we have to discover. Who knows, maybe you'll be the next Volta! Here's what we do know:

Everything in the universe is made up of different kinds of tiny particles that you can't see. These are called atoms. Atoms are made up of even tinier particles. One type of particle is called an **ELECTRON** (the greek word for Amber!), and it has a negative charge. Another type of particle is called a **PROTON**, and it has a positive charge. Some materials have more electrons, and others have more protons.



When things with different charges come together, they want to balance out. When electrons move from a place where there are too many to a place where there are too few, that is called an electrical current. Remember when you rubbed the sock on the carpet and held it up to your hair? That's what was happening!

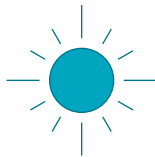
BUT WHAT ABOUT YOUR SOLAR PANEL?

Just 40 years after Volta made his battery, a French teenager named Edmond Becquerel was working in his dad's lab when he had a breakthrough. If he precisely placed two oppositely charged metals in acid and exposed them to sunlight, they generated electricity!

INVENTORS = AWESOME

That was just Step 1. Step 2 was to create an actual solar cell, and for that we thank American inventor Charles Fritts.

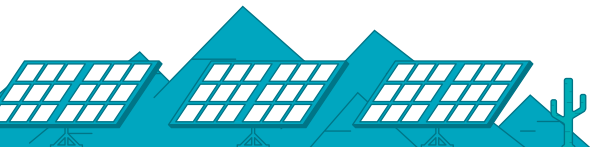
Then some German guy named Albert Einstein published Nobel prize winning research on the photoelectric effect and then 50 years later, the American trio Daryl Chapin, Calvin Fuller, and Gerald Pearson used that research to create the first modern solar panel.



HOW SOLAR PANELS WORK

A solar panel works by allowing photons of light to ram into atoms on the surface of solar panel, knocking free some electrons. Then where do they go? Remember that electrons are negatively charged!

Just like a battery, the photovoltaic cell is a sandwich of two different materials - the top layer is negative, and the bottom layer is positive. When sunlight knocks the electrons free, they want to balance out, so they travel away from the top negative layer to the bottom positive layer, generating an electric current!



SO NOW WE UNDERSTAND THE
BASICS OF SOLAR PANELS,
BATTERIES AND ELECTRICITY -
BUT WHAT ABOUT LIGHT ITSELF?

HOW DO WE MAKE THINGS
LIGHT UP, BESIDES
SETTING THEM ON FIRE?...

"I'M SO FAST THAT LAST NIGHT
I TURNED OFF THE LIGHT
SWITCH IN MY HOTEL ROOM
AND WAS IN BED BEFORE THE
ROOM WAS DARK"

Muhammad Ali, Boxer / Activist



CHAPTER THREE

SHINE ON!

ACTIVITY 6

WE MAKE THINGS LIGHT UP BY USING THE ENERGY WE STORED! How do we do that? Head back outside and gather up the solar panel and battery you left charging in the sun. It's time to put the battery to work!

1. Move BYOL out of direct sunlight, and unplug the solar panel from the battery.
2. Plug the battery into the light board. Press the power button.
 - It turns on, even without the solar panel! That's because the battery stored the power the solar panel collected from the sun.
3. With the light still turned on, begin to add more LEDs, one at a time. What do you notice?

ACTIVITY 6

The light gets dimmer each time you add an LED! That's because each new light needs to use a bit more of the stored energy to keep working. The more energy they use up, the less there is to go around.



Think about it like pizza. If there's only 2 of you, you each could eat half the pizza. But if you're sharing the pizza with 7 other people, you will only get one slice each!



BUT HOLD ON A MINUTE!

That explains where the power goes, but it doesn't explain how or why the lightbulb turns on. To understand that, we have go back in time.

WAYYYY BACK IN TIME...

OVER 125,000 YEARS AGO

Humans figure out how to make fire.

AROUND 70,000 YEARS AGO

We figure out how to make torches by hollowing out rocks or finding shells, filling them with moss soaked in animal fat, and lighting it on fire.

PRETTY DARN CLEVER!



NOTHING FOR AROUND

ANOTHER 70,000 YEARS

STILL NOTHING...

3000 B.C.E

Oil lamps and candles begin to appear around the same time.

ANOTHER BIG JUMP

1780

Someone finally figures out that if you surround an oil lamp with glass, it's a whole lot safer and brighter. 12 years after that, Scottish engineer William Murdoch figures out how to do it with gas.

1800s

We start building bigger and more complicated machines, and we drill for oil.

1840s

We learn to make lamps that run on the oil we found in the earth called kerosene, and millions of people around the world still use them today.

While cheap, **KEROSENE IS DANGEROUS.**

It sends a toxic substance called black carbon into our atmosphere, eroding the ozone layer that surrounds the earth, which protects our oxygen supply. Kerosene is also super harmful to be around in general, and can put you at risk for all sorts of lung diseases. We had to find a better way.

1856

Humble German glassblower Heinrich Geissler finds a better way... by trapping an electric arc in a glass tube! The technique he used is still how they make neon signs to this day.

1867

Remember Edmond Becquerel, the 19 year old whiz kid who figured out photovoltaics? He also invented the fluorescent lamp — you know, those long white tubes you find in the ceiling of every building. No big deal...

1874-80

Different people all claim to have invented the electric (incandescent) light bulb around the same time.

1882

Thomas Edison opens Pearl Street Station, the first ever factory lit entirely by electricity.

1893

Nikola Tesla takes things up a notch when he demonstrates wireless electric lighting, blowing everyone's minds.

SO HOW DOES A LIGHT BULB ACTUALLY WORK? It converts the electric energy from the battery back into light energy. Inside each glass bulb there are two wires that stick into the air. One has a positive end and the other is negative. They are connected by a thin strip of metal called a filament – this is made of a strong metal that is super hard to melt. The glass is also filled with a gas called Argon – this also helps stop the metal from getting too hot and becoming dangerous.

When you turn on the light, you send electrons from the battery up the wires to the filament. As the **ELECTRONS BECOME MORE EXCITED**, they heat up and bang against the filament and it begins to glow! You get different color lights with different types of metals. This all happens in the blink of an eye!

1962

Nick Holonyak Jr develops the first LED (light emitting diode). It can only emit red light.

1995

Shuji Nakamura invents the other LEDs that allow your light, your TV, your cell phone, holiday decorations and even the lights you see at construction sites to work!

SO THERE YOU HAVE IT!

ACTIVITY 7

Connect the solar panel back into the battery. You now hold in your hands a fully functioning, portable, solar powered LED light!



YOUR TURN

LEDs are the result of over 100 years of fine tuning the idea behind the light bulb. Thanks to Nick and Shuji, we can now make lights that are way **SMALLER, BRIGHTER AND MORE EFFICIENT** than Tesla or Edison ever could have dreamed.

If we know anything about science and technology, it's that the only way we make progress is by trying new things. By asking questions. Questions like **"WHAT IF?"**, "why not?" and "how can we make this even better?"

It doesn't matter if you make mistakes — sometimes mistakes lead to amazing new discoveries! If you're curious about the world and open to new ideas, anything is possible. What will you dream up?

GET OUT THERE AND EXPERIMENT!





BUILD-YOUR-OWN-LUCI

A BRIGHTER WAY TO PLAY