ELECTRICITY
How it works & how we use it

Zero Waste Cooking:
makes the most of your food

DIY: turn an old shed
into a plant grow room

YURTS:
Simple, Sustainable Dwellings
GREAT SAWMILLS. SHOCKING VALUE.

Premium band sawmills from only $4397.00. Get your free kit!
Toll Free: 800-661-7746 EXT 660

NORWOOD
NorwoodSawmills.com
Projects

Turn a Shed into a Grow Room

Food & Gardening

My Journey to Zero Waste Cooking

Photo Journal

Homesteads & Farms Around the World

Dwellings

Yurts: Sustainable Living in Simple Shelters

Energy & Tech

Electricity
Have you ever tried starting seeds indoors with big dreams of a nice crop of lush and bountiful plants (that would be the envy of all of your greenhouse-shopping friends, of course) to transplant into your garden, but ended up with weak, spindly things that are too frail to survive outdoors? If so, you’ve already learned from experience that if you don’t have ideal growing conditions, your seeds might germinate but may not get anywhere near their full potential. Having started many, many seeds indoors that haven’t always grown into the robust plants I have aspired to cultivate, I know this frustration all too well. Like many gardeners, I have always wanted a greenhouse, or at least an area where I can grow seedlings as healthy as my favorite local plant nursery does, and be able to transplant these well-established plants outdoors as soon as possible in the spring to maximize on our short growing season.

The proper mix of lighting, temperature, and moisture is the key to getting great results with seedlings, but achieving this is often easier said than done. Greenhouses are ideal for raising plants, but can be expensive and labor-intensive, and many people don’t have the space to dedicate to creating indoor growing areas. That’s why I was so interested in a project my aunt and uncle, Tammy and Don, took on this past winter: turning one part of an old, unused shed on their property into a little grow room where they could get an early start on their garden plants. When Don recently told me about the amazing crop of plants he had filling up that space, I had to drive out and take...
For less than $50 in materials, they converted just one side of the old shed into a growing area that produced plants better than anything I’ve ever seen at our best local plant nursery. Seriously!

The shed that they used to build the grow room is nothing special, just an old wooden thing on their property that they weren’t using for anything else. It had a couple small windows on one long side, but they wanted bigger windows on the south side for maximum sun exposure. A neighbor happened to have some old widows on his property that he was going to throw away, so Don got a couple of them and installed them in the south wall of the shed. He then used some scrap wood to build a shelf inside the shed in front of the new windows for the plants to sit on.

Next, the biggest challenge: heat. They needed to find a way to keep the shed warm enough for the seedlings to survive our unpredictable early spring weather until it got nice enough to move the plants outdoors. Don used foam sheeting cut to fit between the wall boards in the shed as a nice layer of insulation. To block off the side of the shed he wanted to use for growing
(rather than trying to heat the whole thing) he built an insulated “wall” out of several layers of heavy plastic sheeting with a layer of carpet underlayment foam in between. This resulted in a heavy and very effective blanket-like insulated wall. He put a floor to ceiling zipper opening in it to make it easy to go into an out of the growing area while keeping the room as airtight as possible. A small space heater in the room provided heat on the coldest days and nights when our spring snowstorms and unusually cold temperatures might otherwise have killed the plants.

To give the seedlings the maximum amount of light, Don installed a fluorescent lighting fixture over the pots and put it on a timer so the plants would receive at least 14 hours of light a day in addition to what sunlight they received through the windows. He keeps the light just a few inches over the plants, moving it up as they grow. I asked him about his choice to use fluorescent lights as opposed to special grow lights, and he said after doing research he saw no benefit to buying the more expensive grow lights. As you can see from the photos, his plants don't seem to be complaining too much.

To keep air circulation going and ensure the seedlings grew up with hardy stems ready to withstand the outdoors, Don frequently opened the windows on breezy days or kept a small fan going in the room. Lastly, he installed and old roll-down blind on the outside of the shed windows to keep the fluorescent light from bothering the neighbors late at night.

Don and Tammy started with over 60 tomato plants in several varieties and about 20 other plants, mostly peppers and herbs. They all grew amazingly well. At the time I took these pictures (in late April), the tomatoes were all over a foot tall with some nearly two feet tall. And there are no weaklings here; these babies are thick, leafy, and ready to go outdoors. Since all the
seeds they started grew so well, they were able to give many of the plants away to friends and family members (yep, I got some, too) while keeping almost 40 to put into their own large garden.

For gardeners looking for a way to grow nice starter plants without breaking the bank, hopefully this little project is a source of inspiration. This is a great way to save tons of money on garden plants and maybe even be able to do like my uncle did and grow enough to help friends and family members get started on their own gardens.

---

Foam sheeting on the walls acts as insulation and a small space heater keeps the room warm on cold days.
Most of you either live off grid using a self reliant lifestyle as your roadmap for daily decisions on every aspect of your life or you’re planning to transition to that lifestyle. Either way you know the resource cycle of consume and discard has already had a tremendous negative impact on the Earth’s ecology. We can see evidence of this daily from the drastic change of weather patterns over the past few decades to the canvas of urban sprawl that seems to be creeping more and more into rural areas of this once beautiful country of ours.

Tired of contributing to this cycle, I decided to change the influence of my purchases on the world around me. I wanted a healthier, natural life for my family no matter my income level. I started researching local
farms, farmer’s markets, and farm stands. I ran across a website called Local Harvest. I read about something called a CSA - community supported agriculture. If you haven’t heard of one yet it basically means you buy a share of a farm’s harvest for the season. You pay a seasonal fee and you get a basket of produce usually on a weekly or bi-weekly schedule.

I know, I know. A CSA membership can’t change the consumerist mindset of the world. But it was the start to changing MY world. And it was a huge step in the right direction. I used that small step to start building a different life for my family. I don’t consider my budget anymore when making purchasing decisions for goods we consume. The value in consumables isn’t in the cost anymore. Their value lies in how much I can get from them once I acquire them.

This was the start of my zero waste journey.

I’d bring home a basket full of greens and vegetables, some I had never heard of, like kohlrabi. I had no idea what to do with kohlrabi, much less so MUCH kohlrabi. I began scouring the internet and found recipes using it fresh and pickled. Every way I tried it, delicious. As a long time greens lover, every flavorful leaf was consumed fresh or preserved. My particular CSA also included eggs in the most beautiful shades of rose and blue.

I learned the best way to deal with a ton of produce is to process it as soon as it comes in the house, because for those of us used to partaking in mass consumerism at a grocery store, we don't realize that REAL food doesn't look like food from the store. Real food
has dirt, bugs, and yes, sometimes it has bird poop on it. So on pick up days I would spend anywhere from 2-4 hours prepping all the goods for storage. The time would depend on the amount and what types of produce was available. Some items are more time consuming to clean and prep.

At the end of the day I'd have this huge pile of produce trimmings mounded in heaps on the kitchen table. I didn't throw it away because the farmers asked us to save all the trimmings for compost. Granted, my fridge and freezer were stuffed after pick up day. But the pile that was considered waste was substantial and disheartening. My money doesn't come easy. When I'm paying several hundred dollars for a CSA share I want my money's worth. So, I got to thinking...

I love to watch cooking shows and public television. I remembered seeing an episode where the chef used vegetable trimmings to make vegetable stock. I had green onion trimmings, carrot trimmings, and a celery core in my fridge one particular day. So, I made stock. I strained the vegetable trimmings out and THEN put them in the compost bucket. It felt great. I wondered what else I could re-use.

I had trimmed strawberry tops. They always have a decent amount of strawberry left attached to the stem. The stems were cleaned. I thought, “What if I macerate the tops like I do the berries?” So I tried it. And it worked, too! I used the bottom of a cup to push down on the tops after I let them sit in the sugar and everything was super juicy. Then I pushed everything through a strainer to get rid of the pulp and fibrous green parts of the stem. I added squeezed lemon juice and made water flavoring.

My best discovery to date has to be greens stalks. You know when you pull the tough part of the stalk away from the leaves before you toss them in the pot? There are a lot of stalks left to throw out. I was kind of stubborn and not wanting to throw them in the com-
post pile and they ended up staying on the table for a few days. I was contemplating cooking them sort of like roasted asparagus. I noticed they had started to shrivel up a little bit. I picked up a handful and was going to go ahead and put them in the bucket and noticed some of the leaf bits had broken off like powder on the table. Another light bulb went off and I thought, “If I let these dry out and puree them would I have green smoothie powder?” It worked, too!

I’ve never looked back.

To me zero waste cooking is more than just using and re-using everything. The zero waste philosophy has spread out into every area at my home. I’ve since graduated from spending money on a CSA membership and started my own garden. Each year I grow more and more. I save the seeds from year to year and share them with friends and family. So my zero waste mindset starts from the ground up if you think about it.

If I do purchase produce at the store it’s usually organic produce on manager’s special that’s too good of a deal to pass up. For example, let’s say I bought a celery heart and some lettuce. Did you know you can take the root of the celery stalk and the root of the lettuce head and replant them to grow more? There’s a whole list of items you can regrow like that.

I keep bacon grease, beef fat, and chicken fat. I re-use the wax paper lining of the whole grain cereal I purchase. When I’m cooking, if a pot can be re-used from cooking one item to the next before washing, I keep re-using it until it has to be washed. I even keep things like pistachio shells. What do I do with them? Give them to the chickens to eat. They love them!

I’m going to get you started on your own zero waste cooking journey with a simple, delicious, and nutrition filled recipe using items you probably have on hand regularly.

Every time I cook with an onion, celery, and/or carrots, I keep the trimmings. I put them in a gallon size freezer bag and tuck them in the door of my freez-
er. I keep adding to it until the bag is at least half full. I also keep meat bones. When we have baked or friend chicken and are finished eating, I keep all the bones and put them in a bag in the freezer, too. When both bags are half full I’ll take them out of the freezer, empty them into a stock pot full of water, and cook on medium low for at least four hours. You can even add eggshells to the broth. They will cook down and infuse the broth with calcium. If you add a couple teaspoons of apple cider vinegar it will help the bones deteriorate so the marrow and nutrition inside will become part of the broth as well.

It’s important to cook on low to get the full health benefits of the nutrition locked in the bones. The longer the bones cook on a low heat, the more gelatin and minerals that will leech from the bones into the stock. You can actually put all these items in a crock cooker on low and leave it cooking for 24 hours or more. This is known as a continual broth. Our ancestors used this method to keep a pot of broth around at all times for cooking and seasoning. Since most items from the larder were dried foods like rice and beans, broth was a daily staple for generations.

For a continual broth you place a whole chicken, or bones from already cooked or raw chicken in a crock cooker. Personally, I never use a whole chicken. I use a chicken in another meal first, and then what’s left is what I make the bone broth with. Place the chicken into a 6 quart crock cooker. Add your vegetable trimmings; they can be any vegetable trimmings you have on hand. Cover with water to the top. Turn cooker on low. After the first 24 hours your broth is ready.

To get the full health benefits of the broth it’s a good idea to drink one quart per day per adult. As the water starts to get low in the cooker, just add more water and let the broth go again for another 24 hours. You can let this go for a week. When the bones fall apart if squeezed between your fingers, it’s time to drain out the broth and store in the refrigerator, throw out the solids, and start another batch.

The solids that are discarded can’t go into the compost because there were meat bones included. But, you can give the discards to the chickens. They love it!

So you see, zero waste cooking isn’t that difficult. It’s a natural byproduct of living a self sustained life. In your mind it will become a logical progression while transitioning from a consumerist lifestyle. You’ll learn to get more from your life by using and re-using everything. You’ll eat healthier, you’ll learn to be a good steward of what you have, and you’ll learn you really don’t need what you’re used to having to make it. The value to that realization is priceless.

April is the author of the book The Beginner’s Guide to Zero Waste Cooking, full of tips on how to invest in healthier, organic foods and to make the most out of those foods. You can visit her website, An Apple a Day Wisdom, to read more about her journey to sustainable living and see more of her delicious recipes.
ROOF SOLUTION FOR CONTAINER HOMES AND STORAGE

Gable roof

Gambrel roof

Galvalume steel panels
Galvanized components
20 Year Guarantee

Standard & custom widths
20 feet length
Optional painting & gutters

FREE delivery (continental USA)

Visit podroof.com/us for more information.

Made in the USA

888-340-5460 salesUS@podroof.com www.podroof.com/us/
Homestead in Montana
Photo Journal

Homesteads & farms around the world
Traditional Polish cottage
Tuscany landscape
Ukrainian homestead
Russian farm courtyard
Rural Canadian homestead
Wooden farmhouses in Poland
Alaskan homesteader cabin
Lithuanian homestead
Romanian farmhouses
New England farm
Farm yard in Estonia
Ukrainian hut
Mongolian nomads
Unconventional housing options have attracted much attention over recent years and are gaining more traction as people gravitate toward living simpler and more sustainable lives. The reasons for this shift vary by individual, but several factors have played a big part overall. The burst of the housing bubble in the US almost a decade ago, along with the resulting impact on the economy, financial markets, and real estate, has made it ever more difficult to obtain traditional financing for homes. This has caused many people to step away from the typically coveted oversized American home - with way more space than the average couple and 2.5 kids really need - and look for smaller, more affordable options. There is also increasing awareness of the environmental impact of large homes that consume exorbitant amounts of energy to
heat and cool, materials to build, and money to main-
tain. The rising costs of energy have many seeking
dwellings completely off the grid, non-reliant on pub-
lic utilities and water. Tiny houses; homes on trailers
that bypass strict building codes, taxes, and expensive
permits; homes made from recycled shipping con-
tainers; homes constructed out of locally sourced and
reclaimed materials; and homes that can be built and
lived in cheaply, without racking up tons of debt, are
all becoming highly sought-after housing options for
many consumers.

Yurts are one such structure that have seen a consider-
able rise in popularity in recent years. These tent-like
dwellings can attribute their surge into the modern
commercial marketplace, in part, to the “glamping”,
or glamorous camping trend of late. “Glampers” are
outdoors enthusiasts who seek more luxurious camp-
ing accommodations than the conventional tent and
sleeping bag that most of us are used to toting into
the woods. As glorified tents that can be ornately out-
fitted with modern decor and conveniences, yurts fit
right into this luxury camping trend; they can be cus-
tomized for weekend warriors to get close to nature
without leaving too many of their everyday comforts
behind. Yurts are not just for glampers, however, nor
are they a new concept. They have been used as homes
by nomadic people around the globe for thousands of
years and they are becoming more widely recognized
as a practical alternative to traditional homes in other
areas.
What exactly is a yurt?

Yurts are sturdy, round tents that have been used by nomads in the steppes of Central Asia since at least 500 BC. As most nomads are livestock herders, they must often move to where resources are available to sustain their animals. This lifestyle requires hardy shelters that can withstand a variety of climate conditions and terrain while remaining relatively easy to relocate. Traditionally, yurts are meant to be quickly assembled and later dismantled and carried in parts by yaks or camels to be reassembled at other sites.

“Yurt” is a turkic word that refers to the round imprint the structures leave in the ground once dismantled. In Mongolia they are called gers, but the concept is the same: yurts have a wide, cylindrical base made from flexible wood or bamboo and a conical-shaped roof of poles attached to the base. The structures are covered in layers of felt or skins for insulation and protection from the elements. Yurts have a door frame in the wall and a circular crown at the top of the roof to which the roof poles are attached. The walls of traditional yurts were made with wood slats lashed together with leather to form an expandable lattice that could be set up and taken down quickly, and the felt coverings were often made out of wool of the sheep from herds accompanying the nomads inhabiting the yurt. In parts of the world where yurts are still used as residences by nomadic people, the construction and materials of ancient yurts has not much changed.

Modern adaptations of traditional yurts, including those marketed as glamping retreats or sold in kits, may use canvas, polyester, or other types of fabric for the covering. They utilize the same lattice concept for the wall, though the materials and hardware can vary by manufacturer. Some use wood lattices, while others
use vinyl or other materials that are more resistant to mildew and the elements. Ropes or cables are usually used to hold together the frame. The base may have window cutouts or more than one door, depending on the size. Most yurts in cold climates use a wood stove for heat, typically placed in the center of the circle with the stovepipe running up through the hole in the roof, though some people choose to keep the stove along the perimeter and run the pipe out through the wall. In cold climates, multiple layers of coverings can be placed on the yurt for added insulation.

The circular construction of yurts makes them incredibly sturdy and (usually) self-supporting, requiring no support columns to carry the weight of the structure, though some large yurts do have two center columns. Their strength comes from the tension and compression that works as a result of the weight of the roof and covering pushing down and out over the lattice wall and a tension band around the perimeter of the base that opposes these forces. This setup and a low profile makes yurts adaptable to a variety of weather conditions, including strong winds and heavy snow, as is evident in their lengthy track record of withstanding Mongolia’s long winters.

**Why live in a yurt?**

One of the primary features that draws many people to yurt living is the simplicity of living in a smaller space with less stuff. While yurts seem to be ideal for living a decluttered life, they also require little upkeep and are inexpensive to maintain - a huge advantage over “regular” houses. While the lack of square footage compared to a traditional house might seem like a big deterrent, you might be surprised at just how efficiently you can lay out your living space in a circle. I had my doubts about this until browsing through many images online (hello, Pinterest!) and whether in a simple, single room yurt or a more elaborate multi-room version, the possibilities are pretty amazing. Yurts come
ily mean living primitively. Look through photos on the websites of some of the popular yurt suppliers for some inspiring views of how modern yurt dwellers are making their yurts into homes.

Many luxury home builders are using the yurt concept in their designs now, creating gorgeous, spacious homes that have every modern luxury one could want while remaining energy efficient and staying within a reasonably small ecological footprint. The Magnolia 2350 by Mandala homes is a perfect example of a beautiful round home, complete with a matching greenhouse. Its size definitely doesn’t allow it into the trendy tiny house (or inexpensive) category, but it is a good representation of a lavish yurt-inspired home.

Their compact shape, light weight, and strength make yurts highly efficient shelters that minimize building materials and leave a very small environmental footprint. They can be built from scratch, or a complete kit with modern adaptations of the traditional yurt features can be purchased from the many suppliers now available. Even luxury yurts purchased in kits are inexpensive compared to the typical mortgage-laden home most mainstream folks are accustomed to. Yurt living is definitely a step outside the norm for modern civilizations, but living in one doesn’t necessar-
For those seeking more basic accommodations, modern versions of traditional yurts are much more budget-friendly but can also be modified to fit any lifestyle. Yurts used as permanent residences are often built onto platforms with spacious decks or even over basements or garages. They can easily be incorporated into an off grid setting without electricity or running water, but can also be plumbed and wired like any other home for those who wish not to sacrifice these conveniences. I recently came across the blog of a couple in Alaska who built a yurt home in 2008 and have been living full time in it, along with their children, ever since. Their yurt sits atop a large, square platform over a roomy garage with a laundry room. A staircase leads up from inside the garage to the yurt, which has a small bathroom, kitchen and main living area, a loft bedroom area, and a small, walled-off room for their children. This yurt also has front and back doors that step out onto the deck and open up to gorgeous views of the Alaskan wilderness. You can see a video tour of their home here.

If the couple in Alaska can reside full time in a yurt, and not seem to be suffering in the least, you’d think it could be managed just about anywhere. Cold is the first thing I think of as being a potential problem in a yurt, so it’s great to see that people are successfully (and happily) living in them in some of the coldest climates in North America. This couple in Montana is another inspiring example; their well-insulated one room yurt is their year-round, off grid home. It’s not huge, but how much does one couple really need? Their yurt has enabled them to get back to basics in every area of their lives, living simply and close to nature. As they both often work from home, high-speed internet is their only connection to the grid. They drive the
twelve miles into a nearby town when they need to, but otherwise have everything they need to live and work in their mortgage-free home in the Montana wilderness. Sounds pretty amazing, right?

Many educational institutions now offer sustainability programs in their academic curriculum, including Dickinson college in Pennsylvania, which has made yurt living a part of their program. At Dickinson, students can harvest food for their dining hall on the school’s 50-acre organic farm and graduate apprentices can live in one of the farm’s solar-powered off grid yurts for the duration of their apprenticeship. One of the apprentices gave a video tour of her yurt home that you can see [here](#). Her yurt is beautifully decorated and filled with all the comforts of home and lots of efficient storage areas. It’s inspiring to see these types of projects at colleges across the world, and they focus they are putting on sustainable solutions for future generations.

You may not be ready to move out of your house and jump into living in a tent (or maybe you are), but if you are thinking seriously about downsizing and taking a big leap into sustainable living, yurts might be an option to consider. There are other factors that have to be taken into account before you go out and buy one, of course, such as having land to place a yurt on and zoning requirements on that land, but many people are finding ways to do this, and are in turn making their goals of living sustainably and debt-free an attainable reality.
So far, we’ve been discussing fuel sources that involve setting things on fire. Now, we’re going to get a little more modern and start talking about that magic blue fire that powers our day to day modern lives. It entertains us when we’re bored, warms us when we’re cold, cools us when we’re hot, thinks for us when we’re too stupid to work out the problem ourselves, and brings us all together into one giant global community. We call this energy electricity, and to many of us, it’s about as magical as the little elves that make our favorite cookies. In this article, we’re going to explore the physical and quantum mechanical properties of electricity, gain a basic understanding of how it works, and see how we generate electricity and get it to do things like bring darkness into light, and take objects at rest and make them go zoomzoom.

What is Electricity, you ask:

Me: Simply stated, electricity is the phenomena associated with the flow of an electric charge, specifically an electric current.
You: Yeah, okay then smart guy, what’s an electric charge?

Me: Well, that’s also simply stated as the interaction of some matter with the electromagnetic field.

You: Simply? You keep using that word. I do not think it means what you think it means.

Me: Okay, you’re just going to need to take it at face value that there’s this field that permeates all of space and time called...

You: If you say “the Force”, ObiWan, I’m going to kick you in the nuts.

Me: No, actually it’s called the Electromagnetic Force...

You: You get it in the shin for half measures.

Me: Okay, okay, just bear with me here. We’ll just call it the EM field then. Anyways, some particles of matter have what’s called a positive charge, and others have a negative charge. Those with the same charge repel one another, and those with opposite charges attract one another.

You: Okay, I grok, go on.

Me: Well, for instance, the proton in an atom of Hydrogen has a positive charge, and an electron has a negative charge. The positive proton attracts the negative electron and the electron ends up in orbit around the proton.

You: How does the proton get a positive charge then?

Me: That’s a really interesting one. You see, a proton is made up of three smaller particles called quarks that come in different colors known as up, down, strange, charm, truth and beauty, unless you prefer top and bottom, well up quarks have a positive 2/3 charge and down quarks have a negative 1/3 charge. A proton has two up quarks and one down quark for a net positive charge of 1, whereas two down quarks and one up quark neutralize each other and leave us with the un-
charged neutron.

You: But... never mind, I’m sorry I asked. So how exactly do these charges flow?

Me: Well, let’s take it down to the level we normally think about when we’re talking about electricity: the application of electricity in the form of electric circuits and ultimately blinky, glowy devices. Electrons move from the negative end of a circuit, called the cathode, to the positive end, known as the anode, and all the blinking lights, whirring motors, and buzzing speakers in between are just obstacles that perform functions based on the paths those electrons need to go in order to get from negative to positive. It’s like a flea circus or an obstacle course for lemmings, except here we’re playing with subatomic particles.

You: You’re messing with me now...

Me: No, no, you see the anode is positive because it has more protons than electrons and therefore has spaces for the electrons to fill up and the cathode has extra electrons to give up and so these extra electrons flow along a conductor until they reach the anode. Eventually the system reaches equilibrium and the charge of the system becomes neutral. We call this: Your batteries are dead.

You: So, why didn’t you just say that electricity is the motion of electrons from a negative cathode to a positive anode through a conductive medium?

Me: I thought I just did?

History of Electricity

Humankind has known electricity since Homo erectus saw a lightning bolt for the first time and thought to herself, “Holy crap what was that?!” Okay, so we don’t have ol’ Homo-es’ diary to confirm this but it’s likely that lightning has been scaring the crap out of us for a very long time. We do know that Thales of Miletus was rubbing fur on amber and generating sparks in around 600 B.C.E., which is the earliest known work on static electricity. In fact, this work was so fundamental to modern theories of electrostatic force that the greek word for amber, “Elektron” has been immortalized as the nom propre of electricity.

The ancient Egyptians had their own encounters with electricity from the electric eel, known as the “The Thunderer of the Nile” which was known as the protector of other fish. The Chinese were familiar with magnetism as early as 400B.C.E. via lodestone magnets and observed how they attracted iron. Four hundred years later they would construct the first lodestone compass.
showing how the Earth itself had a magnetic field, though the Olmec had made a similar discovery over a thousand years earlier. Unfortunately, they didn't have PlosOne or Phys.org in those days so they couldn't do any peer review and possibly beat Elon Musk to the Tesla Roadster. Though, to be fair, the internet couldn't have happened without electromagnetic theory, so there is that whole chicken-egg paradox to contend with. It would take another thousand years for the Chinese to realize the value of the lodestone compass in navigation by always pointing to “true north” or as we now know it “magnetic north”.

There’s debatable evidence that in the early centuries of the Common Era during the Parthian Empire in what is now known as Iraq, that the people there had discovered a basic electrochemical cell known as the “Baghdad Battery”. Though only one such object was found among many other containers that were used for storing scrolls, the design would have only allowed a few volts if it was feasible at all. Experiments were made to show that the object could have been used for electroplating, but changes to the extant design were required to make this happen. It was extremely unlikely that such a battery could power a giant light bulb as some cranks would like to believe.

It wasn’t until the 1600’s though before real work on electricity started moving along. William Gilbert took the Greek word for amber, “Elektron” and coined the New Latin term “electricus”. He discovered other substances that could contain a static charge such as sulphur, wax, and glass and between these and numerous other important discoveries he was awarded the title of founder of the electrical science.

Electrostatic force could be displayed with two hanging balls charged by rubbing a rod and forcing them to push... hold on, let’s step back from that one a minute. The balls here are light glass spheres dangled from something and when you rub a rod of some material, originally amber, you peel off electrons from the cloth and they collect on the surface of the rod and can then be deposited onto a glass globe via contact with the rod. Charging both spheres causes each ball to repel the other, thus the electrostatic force.

Gilbert’s work was followed by Otto von Guericke, Robert Boyle, Stephen Gray, and C. F. du Fay. Benjamin Franklin threw his hat into the ring a hundred years later with that whole key-tied-to-a-damp-kite-string thing, and the research just kept piling on from there. Luigi Galvani shocked some frog legs and therefore discovered bioelectricity, and you’ve probably heard of the Galvanic Skin Response. Alessandro Volta broke into the 19th century by inventing one of the first batteries, which we’ll discuss in a moment. Hans Christian Ørsted and André-Marie Ampère first recognized that the electric and magnetic forces were parts of the same whole, and Michael Faraday invented the electric motor in 1820 (Nope, Tesla invented AN electric mo-
tor, not THE electric motor). Electricity was the new hot enchilada in the scientific community so this list of names could go on for several pages, though the brilliant minds of Georg Ohm, Alexander Graham Bell, Ottó Bláthy, Thomas Edison, Galileo Ferraris, Oliver Heaviside, Ányos Jedlik, Lord Kelvin, Sir Charles Parsons, Ernst Werner von Siemens, Joseph Swan, Nikola Tesla, and George Westinghouse, turned electricity from simple scientific curiosity into the driving force of the Second Industrial Revolution. Heinrich Hertz discovered that ultraviolet light shining on an electrode made it spark more readily, which lead to Einstein's 1905 paper on the photoelectric effect, and ultimately photovoltaic solar panels, but we'll get there in a minute.

Special mention must be made of James Clerk Maxwell, especially in his “On Physical Lines of Force“ in 1861. Maxwell joined electricity, magnetism, and light with a single simple set of equations that were later refined by Hendrik Antoon Lorentz who then inspired the work by Albert Einstein on relativity.

**Electromagnetism**

**Electromagnetism**: The concept here is simple - electrons moving through a conductor generate a magnetic field (battery + copper wire + iron nail = electromagnet) and magnetic fields moving along a conductor moves electrons (rare earth magnets + copper wire + motion = electric current). This is where the generator comes in. Apply motion to the generator and you get electricity; apply electricity to the generator and you get an electric motor.

**What makes a material an Insulator v.s a Conductor?**

Everything is made of atoms. Atoms are made of protons, neutrons and electrons. Electrons orbit protons at certain energy levels. Electrons at the outermost energy level or “shell” can leave their orbits and flow as charge carriers throughout the material that the atom makes up. The amount of energy it takes for these electrons to leave their outermost orbits is known as the energy gap or the band gap of a material. This “gap” is the difference, in electron-volts between the valence band (the maximum energy range where electrons live at absolute zero temperature) and the conduction band (the energy level where electrons move freely throughout a material). Those materials with a large band gap are not likely to give up their electrons easily and are known as insulators while those with a very low or zero band gap give away electrons freely and are known as conductors. There is no perfect insulator, however. With enough energy, even materials with the highest band gap will give up their electrons and conduct electricity.

**Types of Electric Current - AC/DC are you ready to rock?**

There are two types of electrical current used by modern electrical devices that we should discuss because they represent very different forms of electricity generation and application. In both cases these currents can be viewed as the motion of electrons, but they move very differently.

**Direct current** is the current used in most digital consumer electronics and other battery operated devices. Direct current, or DC, is the direct flow from point
A, the cathode, to point B, the anode. Electrons flow in one direction, and do all their work along the way. The best analogy here would be pouring a glass of water into a tube. The water goes in, and the same water comes out at the other end. It might spin a water wheel along the way, but the water goes in one end and out the other.

**Alternating current**, on the other hand, works more like a wave in the ocean. The wave is a pattern of motion through the water. A wave might move from point A to point B but the water itself has a net motion of zero (currents are a different story). If you’re sitting in the ocean and a swell lifts you up on the way to the shore, you’ve technically just become part of the wave. In the parlance of electricity, Alternating current, or AC, is the back and forth motion of electrons. What this means is that when a generator at point A moves electrons in one direction, the current is then reversed and those electrons move back to where they started. This sends a wave of electrons through wires and transformers to your electrical box and ultimately into the light bulb that I hope just went off over your head. The electrons in the light bulb, and in the wire, were already there; they were simply moved as a result of the motion initiated at your local power plant. Just like “the Wave” in the crowd at a football game, the people in the crowd didn’t really move anywhere, but the wave itself went all the way around the stadium. This method of generating electricity travels better over long distances than direct current since you are transmitting a pattern rather than actual electrons. This same principal is used in radio transmissions by sending out waves in the electromagnetic field known as photons. Converting between these types of currents requires either a rectifier to go between AC to DC which you’d probably recognize as a “wall adapter”, or computer “power supply”. Or an inverter to convert from DC to AC.

**Generating Electricity:**

There are three primary forms of electrical generation in use today that convert various forms of energy into electrical energy for use in electrical devices.

**Mechanical:**

Most electrical generation is the conversion of mechanical energy (the energy of motion) into electrical energy. In the early 1830’s Michael Faraday build the first electrical generator. The “Faraday Disk” as it was called was a copper disk that rotated between a horseshoe magnet and generated a few volts of DC electricity. During that same time, Hip-
Hippolyte Pixii developed the dynamo, in which a spinning magnet rotated near coiled metal wire. The Dynamo created spikes in electrical current that we now call alternating current, and so Pixii also developed the commutator which allowed the AC to be delivered as DC. Today we use alternators (like the one in your car) to produce the AC electricity that is delivered through wires to homes across the world. While this is not the only means of generating electricity, even mechanically, if you’re turning a wheel by some source of mechanical energy then there is probably an alternator behind it. The most common method of transferring heat energy into mechanical energy that turns an alternator is the steam turbine. Sir Charles Parsons invented the steam turbine in 1884 and we’ve been using it ever since.

Dynamo
Electrochemical (Batteries):

The History of the Battery goes back to about 1800 when Alessandro Volta first created what is known as the voltaic pile which consisted of copper and zinc plates separated by an electrolytic substrate, usually a piece of cloth or cardboard soaked in brine. These can be made at home using nickels for the zinc, pennies for the copper and a paper towel soaked in salt water for the electrolyte. Each layer by itself doesn't produce very much voltage but when stacked in a series the voltage can be increased. What's happening here is that the zinc is dissolving into the electrolyte, stealing oxygen from the water in the electrolyte which creates zinc oxide and leaves 2 extra electrons behind which need somewhere to go. This also deposits a pair of positive hydrogen ions on the copper layer which steal a couple electrons from the copper and often bubble away as hydrogen gas, which causes leaks, making the voltaic pile unsuitable for contained, portable applications.

The dry cell is probably what you think of when you think of portable batteries today, and it was invented in 1887 by Carl Gassner. The overall design is based on the wet Leclanché cell but rather than using a wet electrolyte, the electrolyte was mixed with Plaster of Paris into a paste that was just wet enough to carry an electric current. National Carbon Company
Zinc-carbon battery, lithium-ion car battery, lead acid battery, and dry cell battery
was the first company to mass produce Glassner’s dry cell in 1896 but they replaced the Plaster of Paris with coiled cardboard, making it easier to manufacture and this became known as the **zinc carbon battery** and it is still in use today, though the basis of the electrolyte has changed over the years.

The problem with most dry cells is that once they’re drained, they’re done for. However, in 1859 **Gaston Planté** invented the **Lead Acid Battery**. It was the first rechargeable battery design and it is still in use today. Lead acid batteries consist of a negative lead (Pb) electrode, a positive lead oxide electrode (PbO2) and a **sulfuric acid** (H2SO4) electrolyte. As the acid reacts with the lead, each electrode becomes lead sulfate (PbSO4) leaving mostly water behind. When charging, the chemical reaction reverses dissolving the sulfur trioxide back into the water and returning the lead and lead oxide electrodes to their original states. Overcharging lead acid batteries can cause electrolysis of the water in the battery which releases hydrogen and oxygen gas. This also reduces the available water in the battery and reduces the storage capacity of the battery. This requires maintenance to maintain the water levels. In the 1970’s, the first gel-cell lead-acid batteries were developed using silica gel to create a fully sealed system. Absorbed Glass Mat or AGM batteries also avoid this maintenance by using a glass fiber mat to absorb just enough electrolyte for the battery to function but prevent evaporation or spillage.

**Lithium-ion** batteries have become the portable power source of choice for electrical automotive systems and portable devices alike. These batteries use the mobility of lithium ions to carry electrical charge from one electrode to another. One electrode is usually either cobalt or carbon and the other a lithium containing compound through an electrolyte. When discharging, lithium ions (Li) travel from the negative electrode to the positive electrode and during charging they flow back the other direction. The electrolyte can vary between aqueous (wet) and nonaqueous (dry) but the identify-
A key feature of a lithium-ion battery is the transport of lithium ions between electrodes.

**Photoelectric Effect (photovoltaics):** Albert Einstein won the Nobel Prize in 1921 for his 1905 paper on the photoelectric effect. His description of light as a particle or *quanta* launched the new field of Quantum mechanics and sent the world down the rabbit hole that this inquiry into the nature of the universe would bring. He would ultimately reject the implications of the science he had done so much to create, but we can't help but thank him for the insights.

The photoelectric effect occurs when certain wavelengths of light strike a metal and eject electrons. High energy light waves, usually ultraviolet in this case strike the atoms of a conductor with a low energy band (I hope you were paying attention) the electrons at the outermost valence level absorb those high energy photons and gain enough energy to leap free of their orbits. These electrons then flow through the metal in a direct current to wherever the metal might lead. This also leaves a gap for other electrons to follow suit and that particular metal atom becomes positively charged. Later Richard Feynman in his lectures on *quantum electrodynamics* would describe the basic principals of the electromagnetic force *thusly*:

- A photon goes from one place and time to another place and time.
- An electron goes from one place and time to another place and time.
- An electron emits or absorbs a photon at a certain place and time.

These basic principals make up the cornerstone to one of the most successful theories in modern physics, allowing us to build everything from solar panels to supercomputers, and it thoroughly and accurately describes the photoelectric effect.

This is the longest article in this series to date, but I've barely scratched the surface on electricity. Previously, I was discussing sources of energy that we converted directly into heat and light through combustion, and these apply to electricity generation in the form of internal combustion engines running alternators as well as heating water to power steam turbines. Up next we'll look at noncombustible sources of energy for mechanical and photovoltaic generation of electricity as well as how these energy sources are used for applications other than the generation of electricity. I wanted to bridge these two energy groups with the form of energy that we use most today so that you are prepared to understand how some of this energy powers our existence in a modern setting. I hope I haven't lost your attention with too much jargon, but some of these points utterly fascinate me and they are difficult to convey without using some technical terms. I hope this has been as fun for you to read as it has been for me to write and you will be ready for the next articles on wind/water power, nuclear power and ultimately solar power. This won't be the last bit of physics I'll throw at you, but without physics, nuclear fission and fusion is just atoms doing stuff to boil water, and that isn't nearly as fascinating as what is revealed by diving into some of the technicalities.