How to Build a 50 MPH

Electric Bike

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1. Introduction

First of all I would like to say congratulations on your decision to build an electric bicycle that will free you from oil dependency, save you money every time you ride, and reduce your carbon footprint. I have been commuting to work for several years now on an electric bike and no longer have to deal with increasing gas prices, parking, vehicle insurance, vehicle break-ins or traffic and I'm doing my part to fight global warming.

My goal in building this bike was to make a fast electric vehicle that would get me to work and back in the same time or less than driving. Actually the bike is faster during rush hour traffic because I can pass all the backed up vehicles by riding in the bike lane and I get away from the stress of sitting in traffic. I had no intension of pedaling the bike when I built it as I have another mountain bike I use for recreational riding. My commute is 15km (9 miles) each way and I do not charge the batteries while I am at work so I needed to have a range of at least 30km (18 miles). I usually cruise at around 65kph (40mph) but occasionally reach speeds over 80kph (50mph). The one-way trip that used to take me up to 1 hour in my car during rush hour now takes me around 15 to 20 minutes on the electric bike regardless of the traffic situation.

I have no engineering or electrical background and didn't know anything about electric bikes when I set out to build mine. I decided I wanted to build a better form of transportation for my commute to work and started doing research. After several years of trial and error building bikes, lots of broken parts, blown controllers and melted connectors I now have a reliable electric vehicle. It easily keeps up with traffic, can be ridden rain or shine, and should last for many years requiring very little maintenance.

With a few basic skills and tools I will show you how to build a high performance electric bike that costs pennies a day to operate and has motorcycle like performance for about the cost of a quality downhill mountain bike. You don't have to be a rocket scientist to build one. If you can follow directions and use some basic tools you shouldn't have any problems.

Why build an electric bike?

You may be wondering why you should build your own bike when you can go buy an off the shelf electric bike or scooter at your local Wal-Mart or Canadian Tire for a reasonable price. The main reason is these bikes just plain suck. They are underpowered with small motors, low amperage controllers, and weak batteries. This is fine if you just want to cruise slowly at 30kph (18 mph) on a flat road down to the local corner store and back and don't mind pedaling to make it up any hill, but I don't see them as a replacement for a car. I fly past people on these bikes like they are standing still. You see them pedaling like mad to make it up a small hill or sometimes pushing them because their battery died. Traffic gets backed up behind them on narrow roads because they are moving so slowly and cars cannot pass them.

There are a few companies that do make very nice high quality electric bikes but only if you are willing to spend up to $10000 and most of them are still not as fast as a bike you can build yourself for a fraction of the cost. If you are serious about replacing your car and cutting the umbilical cord to the oil companies you need to build the bike yourself, hand pick good quality components and modify some parts to increase performance and reliability. This way you can build a bike that perfectly matches your specific needs and will last for many years.

You may be thinking why not just build an electric motorcycle instead of using a bicycle as a platform. Well the bicycle has several advantages. In most places you do not have to license or insure an electric bicycle, which can save you thousands of dollars a year alone. You can also ride an electric bicycle on designated bike routes and paths. On a motorcycle you are obligated to obey the same rules as a car so you are stuck waiting in traffic with every other vehicle. A bicycle weighs much less than a motorcycle chassis, which means it will require less power to move it. This translates to a more efficient vehicle that can use a smaller (therefore cheaper) battery pack to travel the same distance. One final advantage of a bicycle is it can be locked up to a bike rack instead of parking in a stall saving you even more money by not purchasing a parking pass.

Safety

If you plan on building a high-speed electric bike I recommend wearing a helmet approved for motorcycle use as well as appropriate protection for the rest of your body including motorcycle gloves and boots. Bicycles are not designed for high-speed use and a failure of any bicycle component could result in a crash causing serious injury. That being said I have been commuting on my bike for several years now and have not had any catastrophic component failures that resulted in a crash. It's a good idea to check your bike over before each ride for any cracks, damaged parts or loose bolts.

2. Choosing a Bike

When most people decide to build an electric bike they usually go down to the local department store and purchase a really cheap bicycle. This is fine for an average electric bike because they are low cost and come as a complete bicycle ready to convert. On the other hand if you are building a high performance 50mph bike the thought of nothing more than $150 worth of low quality bicycle between you and the road is not very reassuring. They also have poor geometry for high speed cruising. That's why I strongly suggest you purchase a better quality bike designed to take severe abuse that has a slacker geometry giving you a more stable platform at high speed. Making the wrong choice here and you will end up with a bike that is difficult to control at speed, as well as not being strong enough to handle the added stress of carrying heavy batteries and motor, hitting potholes and bumps at high speed and the demands of heavy braking.

You could go purchase a new bike from a reputable bike shop (not a department store) that meets these requirements but it will be expensive and eat into you're ebike budget (we haven't talked about the price of batteries yet). I recommend looking at a good condition used bike or bike components on eBay, pinkbike, or craigslist. This way you can buy or build up a really good quality bike for only a bit more money than a cheap Wal-Mart bike. I will discuss the major bike components separately if you choose to build up your own bicycle piece by piece but you should be able to find a complete bike that meets all these recommendations quite easily.

Frame

The best type of frame to start with is a mountain bike frame as they are available in a freeride and downhill configuration. Cross-country type mountain bikes are built with lightness as a priority and they do not have the best geometry for high speed riding.

Freeride and downhill mountain bikes are designed for strength. These bikes are not used for very much uphill riding so the extra weight that comes from beefing up the frame with additional bracing and thick welds is not a concern. They are usually made from high quality aluminum and are designed to withstand massive abuse from huge jumps and drops without breaking and they also have a nice

slack geometry (lower head angle) which helps keep the bike stable at high speed.

The head angle or angle at which the fork comes out of the frame affects how the bike handles. The steeper the head angle (closer to 90 degrees) the twitchier or unstable the bike will be at high speed. A slacker head angle (closer to 0 degrees) will be more stable at high speed but lose some stability making slow tight turns. A slack head angle also lengthens the wheelbase of the bike, which further improves high-speed handling. The head angle on freeride/DH frames varies from about 64 to 69 degrees depending on the intended use of the bike but I think 66 to 68 is a good number to aim for. Bicycle manufacturers will list this info on their website under frame geometry.

There are other factors of frame geometry that can affect bike handling and it can get very complicated but as long as you start with a downhill or freeride type frame you should end up with a good handling bike. A freeride frame will handle a bit better than the downhill frame at low speed and vice-versa at high speed.

These types of frames are available in a full suspension configuration or as a hard tail, which only has a front suspension fork. The advantages of full suspension frames are obvious giving you a nice smooth ride as the fork and shock absorb the bumps on the road but they also have a few disadvantages. The rear suspension system takes up a lot of space inside the frame that could be used for locating more batteries and they cost a lot more than a hard tail frame. If you don't need very long range from your bike, hence you do not need a large capacity battery; the full suspension frame may be a better choice. I chose a hard tail because I wanted to maximize battery storage space inside the frame giving me the highest capacity battery possible. I ride mostly on smooth paved roads so I can live without the rear suspension. If you use a wide, high-volume tire on the rear wheel it will help absorb small bumps making a full suspension bike unnecessary.

When selecting the frame you want the biggest frame possible to give you the largest battery storage area inside the triangle of the frame. I tested bikes by lowering the seat to its lowest possible position and making sure I was only an inch or two away from resting my feet flat on the ground while sitting on the bike. This is important because when the bike is built it will be fairly heavy and trying to remain balanced on the bike while stopped at a red light can be

difficult if your feet are not flat on the ground. If you decide to use smaller diameter rims, which will be discussed later, it will help to lower the height of the bike allowing you to use a bigger frame. I normally would ride a small or medium size mountain bike frame but for my electric bike I upsized to an XL frame. This gives me ample storage space in the center of the bike for batteries, yet with some minor frame modifications and smaller rims I am still able to rest my feet flat on the ground when seated.

Below is a used 2007 Norco Sasquatch I purchased for $500 off craigslist for this build. Its an XL frame size, has a 67 degree head angle, Marzocchi Z-1 fork with a 20mm axle, Hayes hydraulic disc brakes with 203mm rotors front and rear, and short stem with wide handlebars. This is an excellent platform for an electric conversion with lots of room for batteries.

Fork

When selecting a fork you need to make sure it is the recommended length to match the frame it is going on. If you purchase a complete bike the fork that comes with it will already be a good match. A fork that is too tall for the frame will change the handling characteristics of the bike and add more stress to the head tube than it was designed for. This could result in the frame eventually cracking from the added leverage. It will also raise the stand over height of the bike, which could make the bike to high for you to comfortable sit on. A fork that is to short will lower the front end, which will effectively increase the head angle and change the way the bike handles.

Some forks have adjustable travel, which can help you dial in the correct height for the frame, but they tend to be more expensive and not really necessary on an electric bike. Just get a fork the same height the frame was designed for. Check the frame manufacturer's website to see what size fork they recommend on the particular frame you have.

Forks can have an air spring or a coil spring and either will work fine. An air-sprung fork can be adjusted using a shock pump to change the air pressure inside the fork. A coil-sprung fork may require changing out the internal coil spring to a heavier one to match the increased weight of the finished bike.

Forks also come with different diameter stanchions (the upper portion of the fork that slides inside the lower portion) ranging from about 32mm up to over 40mm. Generally the bigger the stanchions the stiffer the fork, which will help prevent the fork from flexing when using the front brake. Because the bike will be quite heavy after all the components are installed it's best to get a very stiff fork that can handle a large 8-inch brake rotor.

There are several different types of axles for mounting the wheel to the fork. You want a 20mm through axle, which usually comes on the larger, heavier duty forks. The larger axle will help to further increase stiffness of the fork and is definitely recommended for a high-powered ebike. Some forks also have dual crowns, one below the steer tube and one above it. This also makes the fork stiffer but I don't believe it is necessary as the newer single crown forks are more than adequate for ebike use.

Handlebars and Stem

This is more personal preference but a few things are worth mentioning. You may want a shorter stem if you upsized your frame as the bigger frame will have a longer top tube than a properly sized frame. A shorter stem (i.e. 50mm) will prevent you from being stretched out to far while in your riding position. Freeride bikes tend to have a shorter cockpit (riding position) anyway as you need to shift your center of gravity quickly while negotiating jumps and obstacles. A longer top tube can actually make it more comfortable for riding on the street but try some different setups and see what works best for you. I like a high-rise handlebar about shoulder width in length (do ten pushups and then measure the distance between the outsides of you hands) and a short stem. This is just my preference because it's the same setup I use on my recreational mountain bikes but do whatever feels comfortable for you.

Pedal Drive train

If you intend on doing some pedaling as well as using the electric motor you can keep the derailleur, rear cassette and front sprockets on the bike. If you do not plan on doing any pedaling you can convert the bike to a single speed drive train. This will free up some space around the bottom bracket to fit a larger battery pack in the frame of the bike and provide room to mount a disc brake on the rear hub motor. By keeping the single speed drivetrain as opposed to removing it all together it's still a functioning bicycle so you shouldn't need to license it as a moped or motorcycle. It's a good idea to check your

local laws first regarding electric bicycles to see what is allowed and what isn't.

For this bike build I went for the single speed drivetrain option, as I do not intend on pedaling. I removed the large sprocket on the front ring as well as the front derailleur and shortened both cranks. The battery box that fits inside the triangle of the bike frame is wider than the distance between the two cranks. By shortening the cranks they will not protrude into the frame triangle area as much when rotating which means the battery box can be made a little bit bigger. This will increase the space available for mounting the batteries. On the rear motor I removed the freewheel cassette and replaced it with a single speed freewheel to accommodate a rear disc brake rotor. These modifications will be shown in detail in the 'Building the Bike' section. I then removed the rear derailleur and added a chain tensioner converting the drive train to a single speed. This still provides a low gear to pedal in an emergency should there be a problem with the bike, it also removes both shifters from the handlebars freeing up space for lights and other accessories.

Brakes

Brakes are a critical part of the bike build. You have two choices, rim brakes or disc brakes. Although rim brakes can be used on an ebike and will work fairly well under ideal conditions there is no comparison to the stopping power of a good set of hydraulic disk brakes.

Rim brakes require much more force on the brake lever to stop the bike, wear through brake pads quickly, heat up your rim to the point where it can actually blow the inner tube, and lose most of their stopping power under wet conditions. This makes riding in wet weather very dangerous. Disc brakes can be cable operated or hydraulic and I recommend the hydraulic version for the extra stopping power and better modulation. Paired with a large 8-inch brake rotor front and rear, hydraulic brakes will stop consistently under all conditions. The size of the brake rotor affects how much leverage the brake caliper has on the wheel. The stopping power increases as rotor size increases so bigger is better. 8-inch rotors are the standard size for downhill bikes and the size I recommend for a heavy ebike. Make sure your fork is rated for use with an 8-inch rotor as not all of them are.

Mounting a disc brake to the rear of the bike when using a hub motor and a frame with 135mm rear dropouts can be difficult but it is

possible with some modifications. There is not much room for a hub motor, freewheel, brake rotor and clearance for a caliper on a 135mm dropout. Each frame will fit differently so I suggest measuring the spacing on either side of the motor and the clearance from the rotor to the frame before purchasing a rear brake caliper. If you purchased an entire bike you may have to modify the rear brake caliper or find a narrower one to make it work with your frame and the hub motor. If your frame has 150mm rear dropouts (some heavy duty downhill bikes come like this) you will have a lot more room to play with and it should be easier to mount a rear disc brake. Just make sure the axle from your hub motor will fit properly in the wider dropouts as they are usually designed for 135mm.

If you don't want to go through the hassle of modifying the motor and/or caliper you can use a rim brake on the rear of the bike and a disc on the front. Just make sure you purchase a frame that has rim brake mounts on the back, which will be an older style frame. This is not a bad option as most of the stopping force comes from the front brake anyway. If you decide to mount a smaller rim on the rear then you will not be able to use rear rim brakes, as the mounts will be to far away from the wheel. In this case to avoid any frame modifications you can purchase a used older style front fork that has both rim brake mounts and disc brake mounts. This way you can have two brakes on the front; a disc brake for normal use and a rim brake for emergency use should the other brake fail. This takes some getting use to because the front wheel can lockup and slide if you slam on the disc brake too hard but once you are accustom to stopping with just a front brake it can work o.k. The best option is a disc brake front and rear and its well worth the effort to make the modifications and do it properly. You will be regretting it latter if you don't.

Some of the newer hub motors coming out now are a little thinner and are designed to use a disc brake on the motor so if you purchase one of these you may not need to make any modifications.

Rims

If you purchase a brushless hub motor it may already be laced to a rim ready to be installed on your bike. If using a lower voltage battery pack it should do you just fine. However if you plan on building a fast bike you will want a 72 to 100 volt battery pack and a high current controller so your rim and spokes need to be a lot stronger than the low quality rim that comes with most hub motors.

These cheap rims can't handle the massive power of a high wattage setup and can develop cracks in the aluminum around the spoke holes as pictured to the right. Its best if you can buy the motor without a rim on it so you can take it to a bicycle shop and have it laced to a stronger rim with better quality spokes. Any rim designed for downhill or freeride type riding will be plenty strong enough and if you can get thick gauge DT Swiss spokes to lace it up you will have a very reliable wheel that should never fail. A wide rim will work well with a wide 2.5-inch tire and give you a nice big contact patch on both wheels.

Another consideration is the diameter of the rim. This can have a big impact on the top speed and the acceleration of the bike. A 26-inch rim (standard mountain bike size) will give you the highest top speed possible but acceleration and hill climbing power will be lower than that of a smaller rim. Just the opposite is true with a small rim. A 20-inch rim with give you loads of torque (so much so it may be hard not to wheelie the bike under full throttle) and a reduced top speed. The difference is in direct proportion to the change in wheel diameter. A 20 inch wheel is 77% the size of a 26 inch wheel; therefore the top speed of the smaller wheel will be 23% lower than the bigger wheel but will have 23% more torque. There is also increased wind resistance at higher speed so these numbers are not exact but it gives you an idea how the wheel size affects performance. With a smaller rim the motor will be turning at a faster rpm than a larger rim if they are both doing the same speed. The hub motors are more efficient at higher rpm so the smaller rim will be a little for efficient than the bigger rim.

I chose rims 24 inches in diameter as a compromise between the two; a little more torque than a 26 inch rim but still with a decent top speed. You can decide what size is best for you based on your top speed requirements, how much acceleration you need, and how hilly or flat the terrain is where you live. A heavy-duty 24-inch rim can be difficult to find. You may have to try a unicycle supplier if your local bike shop doesn't carry any. I purchased two 24-inch double walled 36 hole 42.2mm wide mountain unicycle rims through www.unicycle.com for $40 each. Make sure the number of spoke holes in the rim matches the number of spoke holes in your hub motor. You could just put a 24" rim on the rear and leave a 26" on the front but by changing both you keep the bike geometry the same, have a lower stand over height, and provide more clearance between the front tire and the lower battery box for the front suspension to cycle up and down.

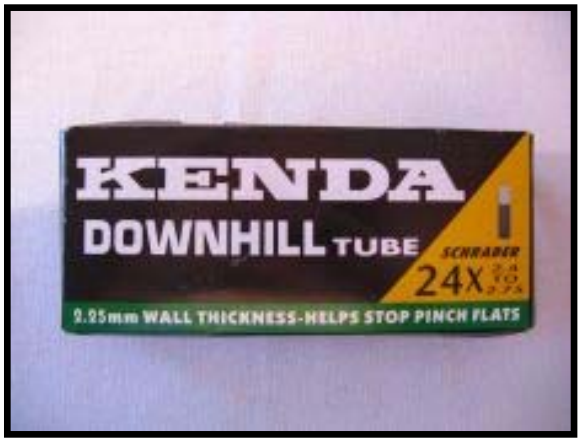
Tires

Tire choice depends on what type of terrain you will be riding on. You want a wide tire to go with your wide rim so you have a large contact patch between the wheel and the ground. Also make sure to buy a thick double ply tire, especially for the heavy rear wheel with the motor in it. A single wall tire is too thin for the additional weight and will flex and puncture easily. If your riding off road most of the time the choice is easy, there are lots of wide heavy-duty downhill tires to choose from. If you will be riding on the street then your choices are fewer as most street tires are narrow with thin sidewalls and there isn't a great selection in 24-inch rim sizes. Look for tires that are designed for aggressive street riding or skate park use. They are usually double ply and have a street friendly tread pattern made from super tacky rubber compound with a low rolling resistance which will make your bike more efficient. I recommend the Maxxis Hookworm tire; they are available in 20", 24" and 26" diameter, are double ply and 2.5" wide.

The last thing you want to do is to try and change a flat tire on the side of the road, especially if it's the rear wheel. The heavy bike needs to be flipped upside down (unless you use a center mount kickstand) and you have to unbolt and remove the torque arm, disconnect the cables from the hub motor, remove the wheel, then fight to get the

thick tire off the rim and finally replace or patch the tube and put it all back together. I have done this several times late at night (when I used single ply tires) in the pouring rain and it's not very fun. You should always carry appropriate tools to repair a flat tire but its best to try and prevent one in the first place.

Purchase the thickest downhill tube you can find that is the right size for you tire. This combined with the double wall tire will provide good resistance to punctures. I use a Kenda downhill tube pictured on the left that is 2.25mm thick. You can also add a Kevlar tire liner between the tube and the tire for added protection but it can be difficult to find one wide enough to protect a 2.5-inch tire.



No matter how thick your tire and tube are they still will not stop a big nail from penetrating so it's a good idea to add some liquid tire sealant to the inner tube. I use a product called Stan's tire sealant available from any local bike shop. Simply add a few ounces inside the inner tube and if a nail punctures the tire the sealant will immediately seal it once you remove the nail and start moving again. Using single ply tires and no tire sealant I would have to change a flat tire once or twice a month. Using double ply tires, thick inner tubes and the sealant I have not had to repair a flat in over a year. The liquid sealant will eventually dry up so it's a good idea to check it every few months and add more if needed.

Kickstand

You definitely need a kickstand to support your bike when parking it or securing it to a bike stand. Your bike can weigh over a hundred pounds when it's finished so you may find a standard bicycle kickstand not strong enough. I purchased a center mount kickstand because it has two legs to distribute the weight better. It also has the advantage of raising the rear wheel off the ground when it is deployed. This makes removing the motor much easier when it's time to change a tire. As mentioned earlier with a rear kickstand you need to flip the bike upside down to remove the rear wheel and this can be difficult because the bike is so heavy. I had a local welder add some bracing to the kickstand to increase its strength and it has held up very well.

Accessories

A few other accessories you may want for the bike include a rear rack, fenders, rear view mirror and a good bike lock.

A rear rack is useful for mounting side panniers so you can carry all your stuff with you wherever you go. You can also add a rear bag on top of the rack to carry tools, a bike lock or anything else you may need. The back of the rack makes a great place to mount a rear light and turn signals.

Fenders are obvious once the rain starts. Any MTB fender set will work fine. For the front fender I drilled some holes in it and mounted it on the lower arch of the fork with zip ties. With the fender mounted in the standard position up high in the fork stem there is a large gap between it and the smaller 24-inch wheel. This allows water and debris to be thrown up in front of the fender hitting you in the chest while

riding. Having it closer to the wheel prevents this from happening. For the rear I used a combination of two fenders. From just behind the bottom bracket area up to under the rear rack I used a cut down full coverage fender. From there I used a section of a wider fender extending out the rear of the rack. They are secured to the bottom of the rack with zip ties.

Since you will be riding with traffic at times you will want to have at least one rear view mirror. I tried many different types of mirrors and I believe the best one is the mountain bike mirror manufactured by Mirrycle Corporation. They are strong, reliable, cheap and available from various online bike shops.

You will need a high quality bike lock to protect your investment when parking your bike. I use a Kryptonite brand New York U-lock. If you use a Hella Master Power switch (discussed later in the book) you can take the key with you when you lock up your bike. This makes it impossible for anyone to power up the bike and ride away if they do manage to cut your lock. They would have to carry or push the heavy bike, which further deters anyone from stealing it.

3. Choosing Electrical Components

Motor

There are basically two types of motors available for electric bikes. One type uses a small motor that is mounted to the frame of the bike and drives the rear wheel via a chain system. These types of motors are commonly found on lower end department store electric bikes and one of the more popular after market conversion kit systems is called the Currie Electro Drive conversion kit. The other type of motor system is a hub motor that is an integral part of the wheel and has the rim laced directly to the outside flange of the motor. This system takes up less space on the bike than the Currie system, has less moving parts, is more reliable and virtually maintenance free. There is also a wide variety of hub motors available with varying power ratings so you should be able to find one that meets your needs.

There are two types of hub motors, geared or non-geared. The geared hub motors have internal planetary gears and are usually smaller in diameter than a non-geared motor. The gears help to increase the torque of the motor, which improves acceleration and hill climbing ability, especially when used with lower voltage (24-36volt) set ups that would normally struggle with a non-geared motor. Some brands of geared motors include BMC and eZee motors.

The largest of the non-geared hub motors are able to handle much higher voltages and power output compared to the geared motors. They have no internal plastic gears to wear out or break and they have physically more mass to help deal with the extra heat generated from running at high wattage. If you want a very fast electric bike there is really only one choice, the Crystalyte 5300 series of hub motors, sometimes called the Crystalyte Phoenix series. These heavy hub motors (23lbs) are able to handle up to 100 volts and 150 amps while still being reliable as long as you monitor the internal temperature closely.

The 5300 series (sometimes called X5 motors) come in several different windings. The three most popular are the 5303 or Phoenix

Thanks for checking out the first twenty pages of my book. Soon you will be receiving another free gift. A pdf file containing a sample of 20 detailed pictures taken from the rest of the book showing you how to start building your very own electric bike.

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