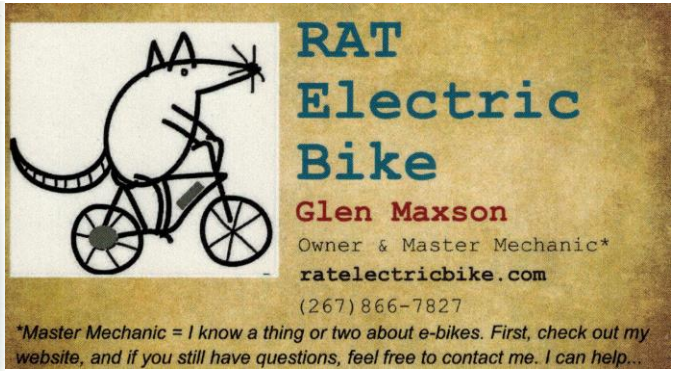
All About Electric Bicycles!

Glen Maxson
Center for Learning in Retirement
Spring 2024

Who Am I



- Penn State grad 1977
- Information Technology (1978-2011)
- Retired from Intel 2011
- Teach Tech to seniors (http://seniortechadvisor.com/)
- Build electric bikes as a hobby (http://ratelectricbike.com/)
- Think electric vehicles are the future (http://drivethefuture.tech/)
- E-bike advocate (https://doylestownpa.org/government/boards-and-commissions/bike-and-hike-committee/) – *meets 3rd Tuesday each month*

Contents

Why consider an e-bike?

- **Benefits** of e-bikes for ‘seniors’ (source)
  - Riding an electric bike for seniors is one of the best ways to **stay active**, improve cognitive function, and stimulate your mind
  - Helps improve your **cardiovascular health** and lower blood pressure, while reducing stress on your joints and muscles
  - Can be safer, and is certainly more **environmentally friendly**, than driving a car
  - It’s a great way to **reduce stress** levels because it helps you get away from your everyday life for a little while
  - Can help you **lose weight**
  - Can enhance **social interaction** and gets you outside, enjoying nature and spending time with others…

In the news

Why electric bikes actually give more exercise than pedal bikes

- **E-bike riders generally ride longer**
  - Electric bikes, which include a motor and battery to assist the rider, tend to rack up more miles
- **E-bike riders tend to use their bikes more often**
  - electric bike riders tend to ride more consistently
- **Tough terrain is easier on an electric bike**
  - Electric bike riders who take to trails will often attempt more arduous climbs than they would on a pedal bike

Who knew?

Time for a short video (2:07min)

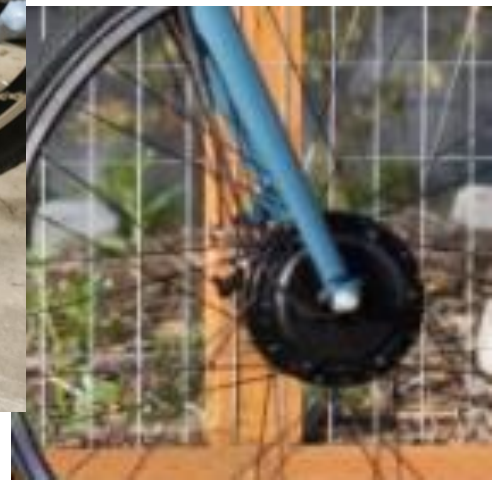
What is an electric bicycle?

- An **electric bicycle** (**e-bike**, **eBike**, etc.) is a motorized bicycle with an integrated electric motor used to assist propulsion.
- E-bikes generally fall into two broad categories:
  - bikes that assist the rider's pedal-power (i.e. pedelecs)
  - bikes that add a throttle

Note: e-bikes must have ‘fully operable’ bicycle pedals, and can have either pedal-assist or throttle, or both

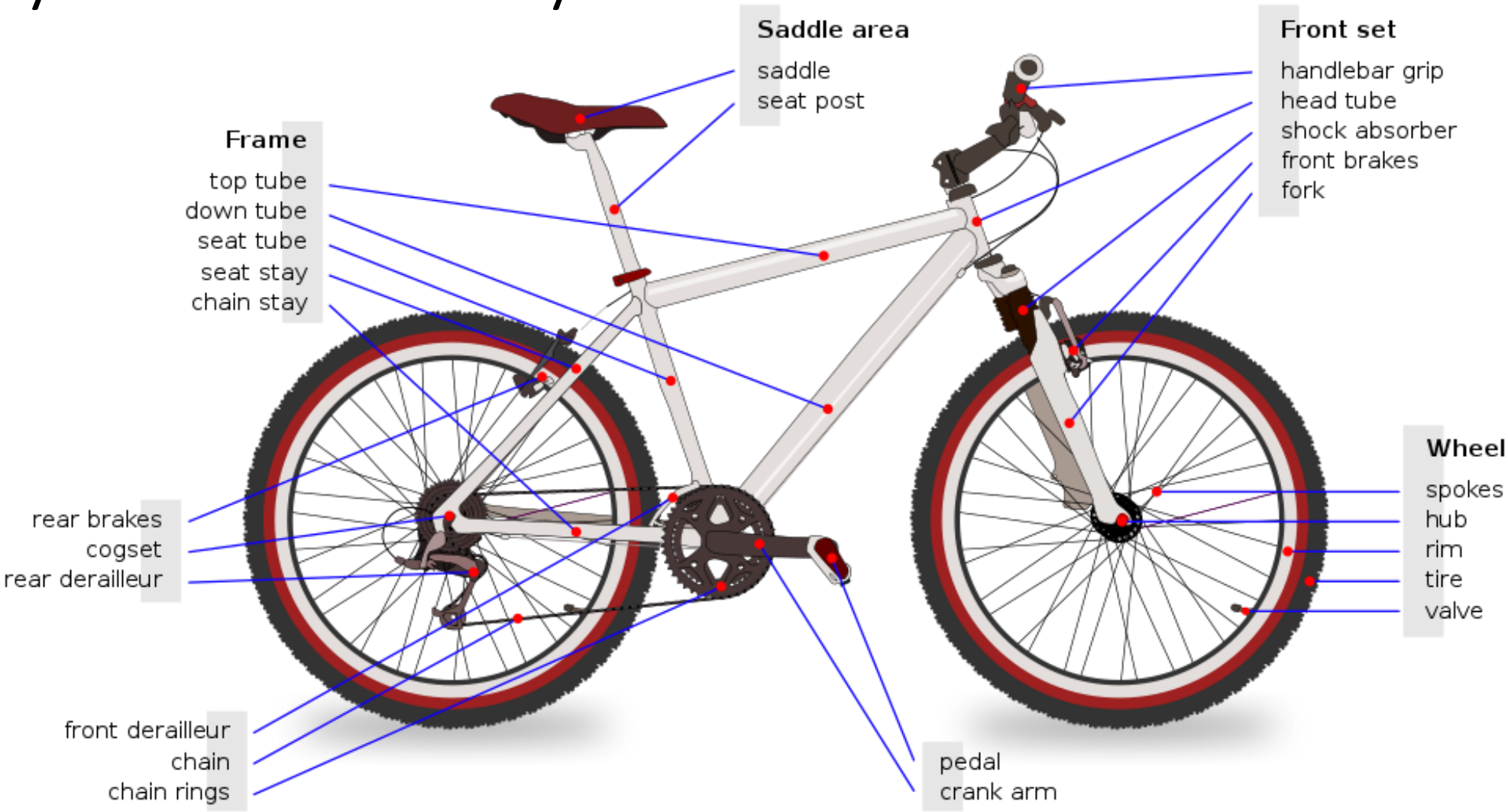
Common locations for an electric motor on an e-bike

- Rear hub
- Mid-drive
- Front hub



- See also:
  - Electric bike motors: everything you need to know
  - E-Bike Conversion Kit Buying Guide

Bicycle Vocabulary



E-Bike Vocabulary

- **Hub motor** - an electric motor located in the front or rear hub
- **Mid-drive** - a motor located at the center of a bike, typically between the pedals
- **Battery** - energy storage that delivers a specific voltage and current to power an electric motor
- **Controller** - an electronic circuit that controls the speed of the electric motor
- **Display** - multifunction lcd display, used to access a variety of functions
- **Motor cutoff switch** - cuts off all power to the motor when a brake lever is squeezed
- **PAS** (Pedal Assist System) - the motor delivers additional power in proportion to the effort being exerted by the rider (incl. cadence vs. torque sensing*)
- **Throttle** – located on the handlebar, allows the rider to engage motor power while pedaling or without pedaling

E-Bike Vocabulary

Torque Sensor vs. Cadence Sensor on Electric Bikes

- Your e-bike will likely be equipped with either one of two sensors: Cadence or Torque
  - These sensors communicate with your bike's pedal-assist system (PAS) to engage the motor and propel the bike forward
- A cadence-based pedal assist system engages the e-bike's motor when a rider begins to pedal
  - As the rider's pedaling speed (cadence) increases, the pedal-assist will reduce the motor's output (power contribution)
  - As a rider's pedaling speed decreases, PAS will increase the motor's output to propel the rider forward
- Think of cadence pedal assist as on-off switch.

Torque Sensor vs. Cadence Sensor on Electric Bikes

- A torque sensor measures how much force a rider applies to the pedals, then determines how much power the motor should output to the e-bike
- Torque sensors make these adjustments in real-time, increasing or decreasing the motor's output in unison with the amount of pedal force a rider applies
  - The harder you pedal, the more output your motor will provide, up to the preset limit for a given PAS level.
  - The less intense you pedal, the motor will meet you where you're at and output less power.
- Torque pedal assist makes sense if you want an experience that's closer to pedaling a conventional bike

Which e-bikes have torque sensing?

- Many lower-cost e-bikes feature cadence sensing pedal assist
  - This is usually the default if torque sensing isn't specified
- In the reasonably priced e-bike category, you'll find bikes like the
  - Aventon Adventure.2, Level.2, and Pace 500.3 all offer 'torque sensing'

E-bike power specs and what they mean

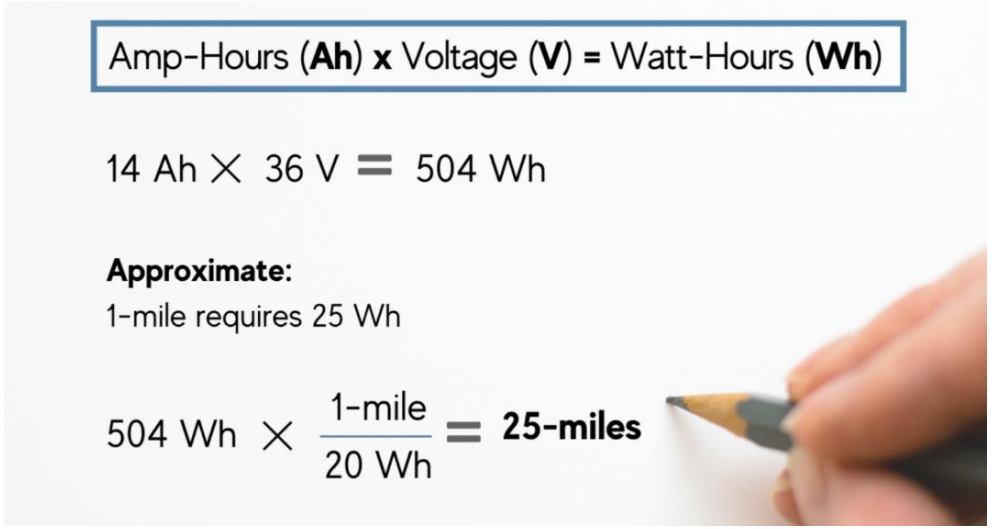
Watt - a unit of power (used to quantify the rate of energy transfer)
Watt Hour - a unit of energy equivalent to one watt (1W) of power expended for one hour
Volt - the electric potential between two points of a conducting wire
Amp – the 'strength' of an electrical current
Or an ampere is an electrical current equivalent to 10^{19} elementary charges passing every 1.602176634 seconds
Amp Hour - how many fixed number of Amps a battery can sustain for one hour
– factor Voltage and Amp Hours together to determine how far you might travel on a full charge*

Calculate - Watts / Volts = Amps

E-bike motors are rated in Volts and Watts
- Bafang BBSHD **48v 1000w** mid-drive motor

E-bike batteries are rated in Volts and Amp Hours
- Joyisi **48v 14.5ah** battery

See also: **Understanding E-Bike Power, Range, And Energy**



So how far will you go on a single charge?

- It depends:
  - Using a real life example:
    - 14.5ah*48v=696wh, then 696wh*(1/20)=34.8miles (~**35 miles** on a 100% charge)
  - Caveat - As long as you use only the throttle, ride on a smooth, level surface with no wind at sea level and 82.4 degrees Fahrenheit, and weigh 170 pounds…
  - In reality, you'll be adding energy through pedaling, so I usually use 35 miles as a worse-case number and expect to get significantly more miles per charge – *I'm actually getting around 60 miles on a 100% charge on my 12.5ah battery! More on a 14.5ah battery I expect (I'm still figuring this out)…*

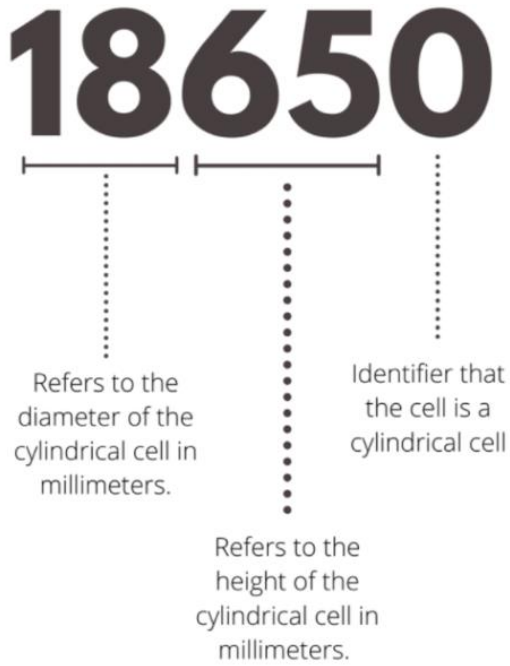
Batteries

- Here's a good article concerning e-bike batteries:
  - Everything you need to know about e-bike batteries [from a battery engineer]
- And another:
  - ELECTRIC BIKE BATTERIES EXPLAINED
- And another, if you're curious how one increases voltage and/or amperage in a battery (basic DC electricity stuff):
  - How To Connect Batteries in Series and Parallel

- Let's talk about battery design, cell chemistry, and care and feeding(aka charging) your e-bike battery

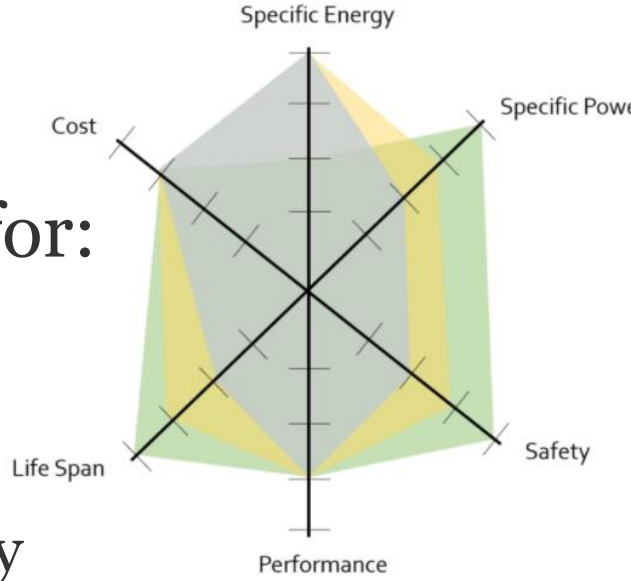
Battery Design

- E-bike battery packs are made up of individual battery “cells”
- The most common form-factor for an e-bike battery pack is the 18650, which is a cylindrical cell with a nominal voltage of 3.7 volts
- Look for cells from Panasonic, LG, and Samsung which have a good reputation for quality
- E-bike battery tech will change as tech for EVs improves



Cell Chemistry

- Lithium-ion (li-ion) batteries are the best option for e-bikes today
- The most popular ones for e-bikes include:
  - Nickel Manganese Cobalt (NMC) – most common!
  - Lithium Cobalt Oxide (LCO)
  - Lithium Iron Phosphate (LFP/LiFePo4)
- When selecting a cell chemistry look for:
  - Specific Energy: has an impact on range
  - Specific Power: how the battery handles high load scenarios
  - Safety: does the chemistry have a history of high in-field failures? (this is bad!)



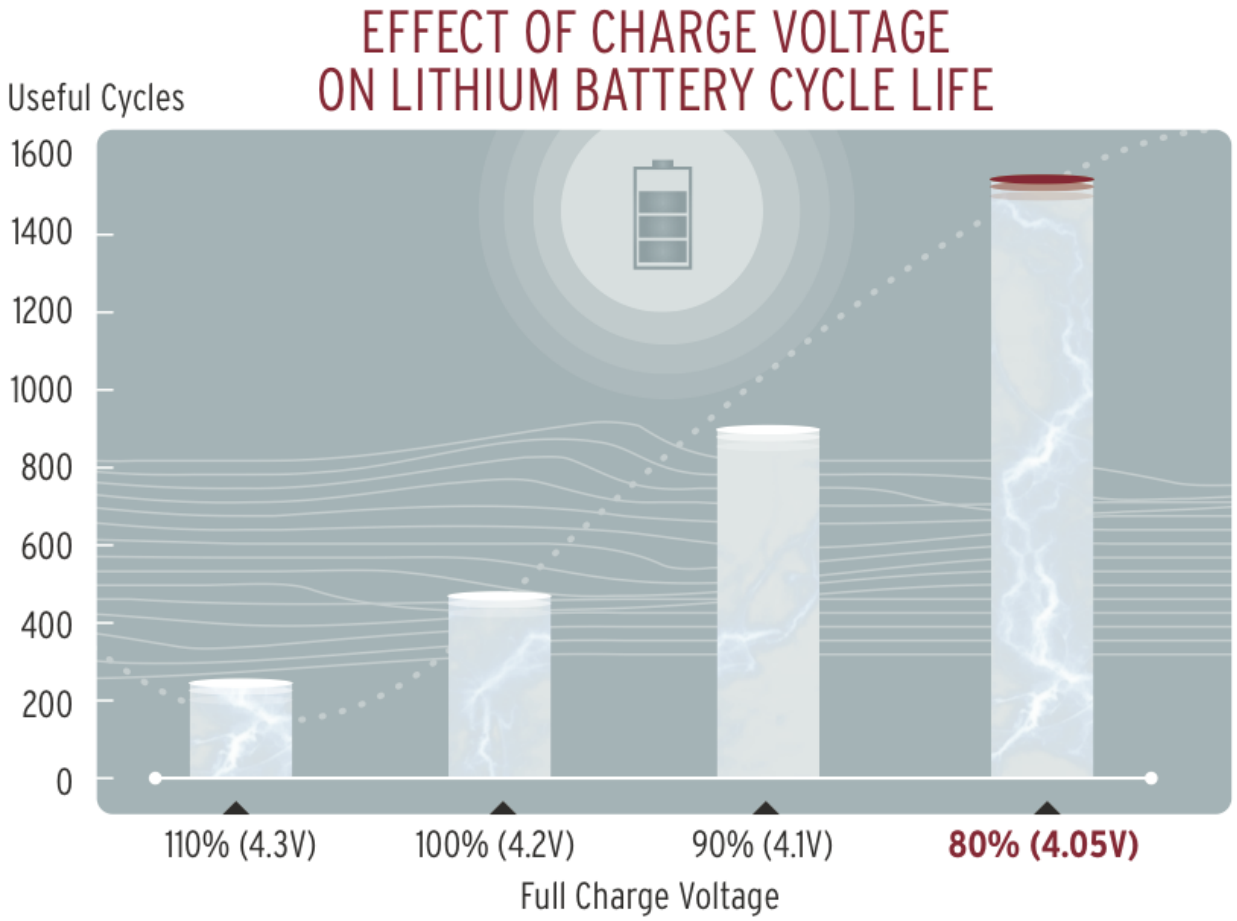
NMC
LCO
LFP

Care and Feeding Your Battery

1. The thing that will kill your battery faster than anything else is leaving it fully charged at elevated temperatures. If it's 80 degrees outside and you have your e-bike battery fully charged, move it indoors where it's cooler and try to drain the battery as soon as possible.
2. Charge your battery at room temperature as often as possible.
3. When sourcing an e-bike battery charger, the slower the charge rate the better. For example, if you have a 2-Amp charger, and your battery is a 14 Ah battery pack, you are charging at 14 Ah / 2-Amps = 7-hours. This is a nice, slow charge which will improve the longevity of your battery. Avoid charging at rates that are faster than 2-hours for a full charge.

- **Bottomline**: Choose LFP or NMC chemistry, slow charge, avoid storing or charging at hotter temperatures, and leave the battery at around 30% charge if you don't plan on using it for a while.

Effect of charge voltage on battery cycle life



Note: This applies to ALL Lithium-ion (li-ion) batteries in cell phones, laptops, e-bikes, and even your electric car!

A word about battery chargers

- The charger you get when you buy a new e-bike or battery will charge your battery to 100% every time. This is not ideal!
- Consider getting one of these chargers from Luna instead:

$99.95 + shipping

Luna Charger 48V Advanced 300W Ebike Charger

or

48v 3amp Luna Mini Charger

$59.95 + shipping

Note: These chargers are designed for 48 volt batteries. If your battery is 36, 52, or 72 volts, there are different chargers available for those batteries here.

E-bike laws - Federal

- At the **federal level**, a 2002 law enacted by Congress, HB 727, amended the Consumer Product Safety Commission definition of e-bikes. The law defined a low-speed electric bicycle as "A two- or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts (1 h.p.), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 pounds, is less than 20 mph." The federal law permits e-bikes to be powered by the motor alone (a "throttle-assist" e-bike), or by a combination of motor and human power (a "pedal-assist" e-bike).

E-bike laws – Pennsylvania State

- At the **Pennsylvania state level** (2014 Act 154), "Pedalcycle with electric assist." A vehicle weighing not more than 100 pounds with two or three wheels more than 11 inches in diameter, manufactured or assembled with an electric motor system rated at not more than 750 watts and equipped with operable pedals and capable of a speed not more than 20 miles per hour on a level surface when powered by the motor source only.
- In addition, e-bikes "do not require a certificate of inspection or insurance" and "are afforded ALL of the rights and responsibilities of other bicycles under PA law".
- See also: PENNSYLVANIA E-BIKE LAW handout, and

A potential fly in the ointment…

Here’s what’s coming –

- California bill would require e-bikers to have license, mandate training
  - Assembly Bill 530 would prohibit people under 12 years old to ride e-bikes, would require an online written test and a state-issued identification for riders who do not have a driver’s license, and would establish an e-bike training program
- Alaska defines e-bikes as "motor-driven cycles" and requires a license to ride.
- Hawaii - E-bike riders are subject to registration documents and must carry an operator's license.
- Massachusetts requires e-bike riders to have a license as well as registration for the bike, but does not require insurance.
- New Mexico defines e-bikes as "mopeds", meaning riders are required to have license and insurance.

Pennsylvania is one of thirty-six states that utilize the three-class system for electric bikes*

E-bike Classifications – 3-tier (source)

- **Class 1:** The Class 1 e-bike provides assistance only when you pedal, and stops assisting when you reach 20 mph
- **Class 2:** The Class 2 e-bike is equipped with a throttle which provides a boost without pedaling, and stops assisting at 20 mph.
- **Class 3:** The Class 3 e-bike is equipped with a speedometer, and only assists until the bike reaches 28 mph

E-bike laws – Local

Hopefully our local community will adopt the Model Electric Bicycle Law from PeopleForBike.org because THIS does not work…
Or adopt this E-Bike Ordinance recently drafted for review by the Doylestown Community Bike and Hike Committee (April 18, 2022)

Maintenance

- Learn how to inspect and care for your e-bike
  - How to adjust your derailleur(s) and brakes
  - Maintain correct tire pressure and know how to repair/change tubes/tires
  - Monitor spoke tension, etc.
- Know what tools and spare parts you need to carry with you when you ride
- And know when to call the pros!

E-Bike - Build versus Buy decision

- The ‘build’ option is for the tinkerer who has some technical skills and ‘shop’ space necessary to do the job and have a safe e-bike in the end
- Building an e-bike will most likely save a considerable amount of money over a commercial e-bike with similar components
- Buying a pre-built e-bike is complicated by the fact that there are many choices and you need to know something about the technology to make an educated purchase decision (hence why you’re here)
- Regardless of whether you build or buy, this IS a bicycle and you’ll need to maintain it. Educate yourself about your e-bike so you know what to watch for, how to make basic repairs, and when to visit your local shop

The DIY Conundrum

- What if you build a 48v 1000w throttle-only e-bike without pedal assist? Where do you fall under federal and Pennsylvania law, and should you care?
- The answers are:
  - you don’t, and
  - yes (you should care)
- The law is clear and you’ll likely be operating somewhere outside your legal protections

Build process

So, you think you want to build an e-bike and save a bunch of money?

- It's doable IF you have some technical skills AND patience (and tools)
- Steps for an e-bike builder:
  1. Find a 'donor' bike
  2. Inventory reusable parts
  3. Purchase replacement parts and necessary tools to complete your build
  4. Order the motor, battery, display, and any essential cables and/or adapters
  5. Watch a bunch of 'how-to' YouTube videos
  6. Start building (repeat steps 3-5 as needed)
  7. Test, tweak, and have fun…

E-bike builds #1 and #5

48v 1000w Voilamart gearless rear hub - TREK frame (hard tail)

48v 500w Bafang geared rear hub - TREK frame (full-suspension)

E-bike builds #3 and #6

48v 1000w Bafang mid-drive
- Gary Fisher frame (hard tail)

48v 1000w Bafang geared rear hub
– (Costco) Northrock XC00 ‘fat-tire’

E-Bikes Available Locally

Princeton eBikes

Redline E-Bikes

Voltage Electric Bikes

Princeton

Gazelle Bikes on Sale – Fully Assembled and Tuned

Medeo T9 City HMB, $1849**

The Gazelle Medeo T9 City is our most affordable mid-drive motor eBike, with the high quality expected from Gazelle. It has a reliable and quiet Bosch Active Line motor and 9-speed external derailleur. Powerful front and rear lighting plus a sturdy rear rack will inspire riders to swap their car for this bike for both day and nighttime trips The frame is a stable lightweight aluminum sloping frame available as a low step and comes in two sizes (45 and 50 cm) and two colors (mallard blue and light olive).

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Electra

Townie Go! 7D Step-Through, $1749**

Electra is a brand of eBikes owned by Trek, a company that has long been known for their quality and durability. We offer the Electra Townie Go! 7D Step-Through which combines quality, comfort, and value with Electra's signature style. The Townie Go! 7D features Electra's patented Flat Foot Technology® for ultimate comfort and control while riding. Reach a top-assisted speed of 20 mph with support from the rear hub motor.

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Velotric eBikes

The Velotric team is comprised of executives from iconic brands such as Lime, Giant, Specialized and Decathlon. We believe ebikes should be elegant, stylish, high performance, reliable, safe and affordable. Our team has worked tirelessly on our design, and listened to users to bring you our flagship model, the Velotric Discover 1 – an ebike with great style, comfort, and engineering reliability. Velotric makes ebikes that are simple to use, comfortable to ride, reliable in terms of performance and quality, and superior in style and fashion.

The Velotric Discover 1, $1199**

Meet Discover 1, Velotric's premium quality, affordable commuter ebike. With a **500W** high performance motor **(peak 900W)** and a **65Nm torque** for a smooth, exciting and effortless riding experience.

Redline

Himiway Cruiser

~~$1,699.00~~ $1,199.00

You save $500.00 (29%)

Color:

Quantity

1

BUY NOW

Redline

Himiway Rambler

~~$1,399.00~~ $1,299.00

You save $100.00 (7%)

Color

-- Select --

Quantity

1

BUY NOW

Voltage

Home / eBikes / Aventure.2 Ebike

Aventure.2 Ebike

For all your all-terrain adventures.

(4.71) 4655

$1799 Starting at $163/mo with affirm.

Frame: Step Over

Size: Regular

Sizing Tool

Slate Grey

Voltage

Home / eBikes / Level.2 Commuter Ebike

Level.2 Commuter Ebike

Our commuter ebike, with torque sensor.

(4.66) 3678

$1699 Starting at $154/mo with affirm.

Frame: Step Over

Size: Regular

Sizing Tool

Clay

Voltage

Home / eBikes / Pace 500.3 Step-Through Ebike

Pace 500.3 Step-Through Ebike

A powerful, easy-to-use cruiser ebike.

(4.72) 4829

$1599 Starting at $145/mo with affirm.

Frame: Step-Through

Size: Regular

Sizing Tool

Blue Steel

Available Online

Rad Power Bikes

Rad

RadRover 6 Plus High Step

$1,199 ~~$2,099~~

Electric Fat Tire Bike
For riders 5'7" - 6'2"

Free, fast shipping

Wait less, ride more. Enjoy fast, free shipping on all ebike orders.

1 year warranty

Ride in confidence. We've got you covered.

Rad

RadCity 5 Plus Step-Thru

$1,699 ~~$1,999~~

Electric City Bike
For riders 4'8" - 6'0"

Decision time

- Build or buy?
- Top bar or step thru?
- Mid-drive or rear hub?
- Power and range – battery removable or not?
- Design – handlebar and seat position?
- Weight – how much is too much?
- Cost – ditto?
- Company reputation and warranty – return policy?
- Maintenance and support – buy locally or mail order?
- Color (really?) – this will matter to some (for me, it must be red!)

A word about e-bike racks

- Traditional bicycle racks usually will not support the weight of your e-bike(s), so prepare to spend a bit more on a rack that does
- There are options: Bicycle Racks (for e-bikes)
  - But this rack from Hollywood Racks is the one I would buy
  - It's the Destination E Bike Rack for Electric Bikes (SKU: HR4500) for $700
  - Here's a great video from Kyle at Area 13 about this rack
    - Hollywood Destination Ebike Rack has a Ramp!
  - And another Destination E-Bike Rack Review

What E-Bike Rack Did I Buy?

Hollywood Racks Sport Rider SE Bike Rack for 2 Electric Bikes – 2” Hitches – Frame Mount for $500

- Pros
  - Capable of carrying two 80lb e-bikes
  - Support tire sizes up to 5”
  - Great design!
- Cons
  - Weighs 54lbs
  - No ramp