

PERSONAL ELECTRIC VEHICLE Buyer's Guide

This guide explains the primary features and benefits that you should understand when considering a personal electric vehicle (PEV), and helps you determine if a vehicle has the correct characteristics to meet your performance needs.

The features covered in this guide are: Road Legality, Safety, Range, Hill Climbing, Battery Charging, Speed and Speed Control.

This guide deals primarily with two-wheel personal electric vehicles, but many of the points discussed are equally applicable to three- or four-wheel vehicles. After reading this guide, you will have the knowledge and tools to effectively compare products based on *your needs* rather than on a manufacturer's specifications.

IN THIS GUIDE

Road legality 2
Major components 3
Safety.....................................4
Range 4
Hill climbing 5
Battery charging......................6
Speed & speed control.............7
Buyer's checklist.......................8

Road Legality

If you are considering an electric vehicle for transportation, it is important to know whether the vehicle is legal to operate on public roads. Road legality, registration, and operator requirements involve federal, state, and local regulations.

The Federal Government regulates Electric Assisted Bicycles and EPAMDs (Segway) as *bicycles* under the Consumer Product Safety Commission (CPSC). To be an electric assisted bicycle, the PEV must have operable pedals, a motor of *no more than* 750 watts (see section on *hill climbing*), and cannot be operated under power *over* 20 miles per hour.

The Federal Government classifies all other two wheel PEVs as *motor vehicles* and regulates them under the DOT using the Federal Motor Vehicle Safety Standards (FMVSS). These standards establish specific requirements for tire performance, tire and rim compatibility, lamps and reflectors, mirrors, braking systems, and vehicle controls and displays. If a vehicle complies with these standards, it will be issued a Vehicle Identification Number (VIN). Without a VIN, a vehicle cannot be registered in a state that requires registration.

In addition to the Federal regulations, each state has its own laws for registration and operation—minimum age, maximum speed, minimum equipment requirements, etc. However, in no case may a state set *lower* standards than the FMVSS, even if it doesn't require that a particular class of PEVs be registered.

If a vehicle does not have a VIN, then it may not comply with local laws, even in states that do not require registration. A VIN ensures that your vehicle has the safety equipment necessary to operate on public roads. To determine the specific laws in your state, contact your local motor vehicle office.

RULE OF THUMB

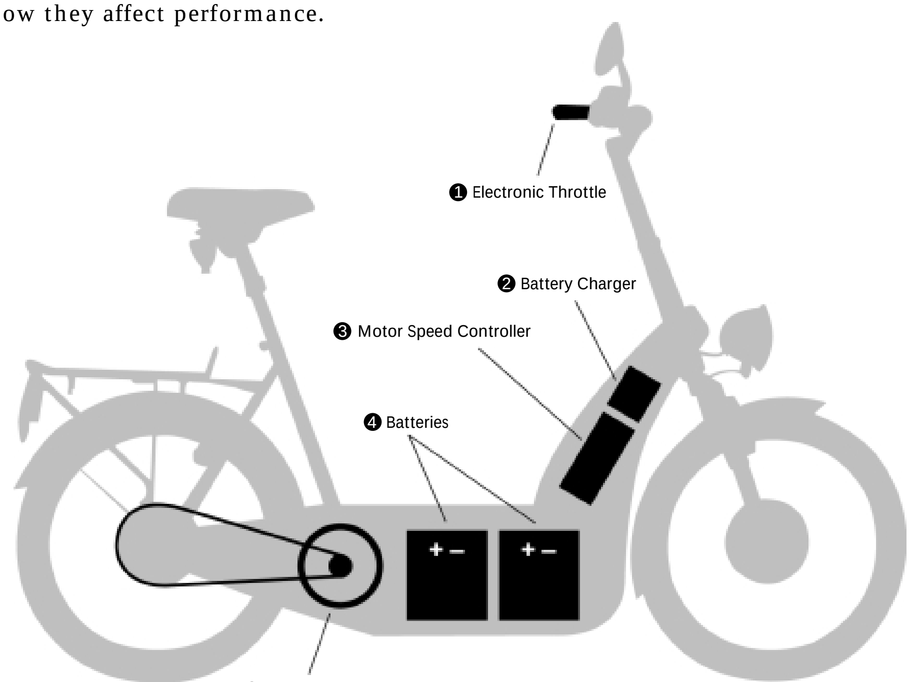
If you plan to operate on public roads (even in states where registration may not be required) you should purchase a PEV with a vehicle identification number (VIN).

QUICK REFERENCE GUIDE TO ROAD LEGALITY

CLASSIFICATION	Electric Moped	Electric Assisted Bicycle	Sit-down Scooter	Stand–up Scooter
DESCRIPTION	High capacity electric vehicle for transportation and errand running	Hybrid mountain bike with electric assist. Mobility assistance for bicycle	Short range, <600W scooter for play or short trips	Short range, <500W stand-up scooter for play/recreation.
EXAMPLES	eGO Cycle, Viento	E-Bike, Giant Lafree	Charlie, Citibug	Currie Flyer, Zappy
COMPLIANCE	Yes (FMVSS)	Yes (CPSC)	No (FMVSS)	No (FMVSS)
ROAD LEGAL	Yes	Yes	No	No
SIDEWALK LEGAL	No	No	No	No
NOTES	Only those with VINs comply with requirements. If over 25MPH, then motorcycle regulations apply in most states.	Brake lights not required under CPSC	No approved tires, rims, lighting, controls, or braking systems	No approved tires, rims, lighting, controls, or braking systems

Major Components of an Electric Vehicle

To help understand the other categories covered in this guide, it's important to know the main components of an electric vehicle and how they affect performance.



1–ELECTRONIC THROTTLE The throttle for a quality electric vehicle sends an electronic signal to the motor controller allowing the rider to precisely and smoothly change and control speed. On budget PEVs, an on/off switch is used.

2–BATTERY CHARGER The charger replaces the energy in the batteries after a long ride. A large charger will recharge batteries more quickly than a small charger. Some are built-in, while others are separate and must be carried along if you want to charge away from home. Chargers are rated in terms of *amps of output*—the higher the amp output, the faster the charge.

3–MOTOR SPEED CONTROLLER The "brains" of an EV; provides electric power to the motor based on inputs from the throttle and also motor speed. Controllers are rated in *volts* (e.g. 24 volts or 36 volts) and maximum current in *amps*. A controller with a higher amp rating can deliver more power to the motor. A high quality controller will allow for smooth and precise control of speed and acceleration.

4–BATTERIES The 'fuel tank' of an EV is the battery pack. Battery packs are rated in *volts* (typically multiples of 12V; i.e. 24V or 36V)) and *amp-hours* of energy. More amp-hours provide more range. (See section on *range*.)

5–ELECTRIC DC MOTOR Drives the rear wheel either directly or through one or more belts or chains. Generally larger motors can produce more torque and more power. Motors are rated in terms of *voltage* and output power in *watts*.

RULE OF THUMB

Not all PEVs are created equal. By understanding and comparing critical components, you can predict how a vehicle will perform.

Safety

The category of safety is too broad to cover in a simple overview, however, there are some important attributes of *vehicle design* that will influence the overall safety of a vehicle. They are:

> RULE OF THUMB
>
> *A good indicator of whether a vehicle* ***meets even basic safety guidelines*** *is whether or not the vehicle has a VIN.*

Wheel size: The larger the wheel diameter, the more stable the vehicle will be, especially when driving over bumps. (Wheels that are more than 16" diameter are safer for typical roadways.)

Center of gravity: A vehicle with a low center of gravity (CG) will be easier to balance and more stable when driving at low speeds. Vehicles with the motor and batteries (the heaviest parts) down low will naturally have a low CG.

Weight distribution: If the weight is too far forward, the vehicle will be unstable over bumps; if the weight is too far back, the front wheel may not track properly.

Lights: Bright lights for driving in low visibility conditions allows you to see and others *to see you*. DOT approved headlights, taillights, and brake lights meet the minimum FMVSS standards for operating at night.

Speed control: One hand speed control is simpler than having different acceleration and braking controls. A vehicle with automatic braking limits maximum speed on hills and automatically slows when the rider reduces throttle.

Suspension: Suspension helps keep the tires on the road in bumpy conditions. A vehicle with suspension will track straight rather than bounce around on rough road surfaces, not only increasing directional control, but also braking ability.

Range

Range is the total distance traveled on a single charge. It is an important factor for electric vehicles and is mainly determined by the amount of energy available from the batteries. Simply put, the batteries are your ‘gas tank’. The bigger the ‘tank’, the farther you go. Other factors that determine range are the number of hills you climb, the combined weight of the rider and vehicle, how aggressively you drive, and the efficiency of the motor and controller.

> RULE OF THUMB
>
> *When determining how much range you will need, add 25% to your total estimated daily use. This is the minimum real life range you should consider when choosing a vehicle.*

Estimate how much range you need (with some to spare) and look for a product that can reliably get you through a day. Consider that a typical charger will need about six hours to fully recharge a PEV (although fast chargers are often available) and that an outlet is not always available at your destination. Therefore, you should choose a vehicle with a range equivalent to your total typical daily use *plus* 25% for safety.

Many manufacturers vastly overstate the range of the vehicle, so be skeptical of the specifications, but generally… *more battery* equals *more range*. To get a more realistic range estimate, seek out real life examples from other owners, or estimate the range a vehicle will deliver by following the example on the next page.

1. DETERMINE WATT HOURS

(_____ x _____) _____ = _____

VOLTAGE AMP-HOURS # BATTERIES WATT-HRS

2. DETERMINE RANGE

_______ ÷ 34 = _______

TOTAL WATT-HOURS | WATT-HOURS PER MILE (APPROX.) | TOTAL PREDICTED RANGE

To calculate the approximate vehicle range, you will first need to know the specifications of the vehicle's batteries. From the number and size of the batteries, you can determine the total usable watt-hours, and then estimate how far the vehicle will travel. Using this approach will help you compare any number of electric vehicles.

1. All batteries have a voltage and an amp-hour rating. This information is usually available in the manufacturer's specifications and is always printed on the battery. To determine the available watt-hours, multiply the voltage of each battery by the amp-hour rating of each battery, then multiply by the number of batteries. For example, if a vehicles uses two 12 volt, 34 amp-hour batteries, then the battery pack has 816 watt-hours of energy.

   (12 volts x 34 amp-hours) x 2 batteries = 816 watt-hours

2. Once you know how many watt-hours the battery pack holds, you can estimate the range of the vehicle. For example, a 170 pound person traveling at 20 miles per hour on a flat course will consume approximately 34 watt-hours per mile of energy. To predict the range of a vehicle, simply divide the watt hours of the battery pack by 34 watt-hours per mile to find an estimate of the range in miles.

   816 watt-hours ÷ 34 watt-hours per mile = 24 miles

Hill Climbing

Unfortunately for a PEV operator/owner, a vehicle lacking the capacity to propel itself and the rider up a hill can cause a permanent and expensive failure. Unlike gasoline motors which simply stop running, when an electric motor isn't strong enough to move the vehicle when the throttle is fully on, the motor or controller will often burn out. So choosing an electric vehicle requires that you consider more than the inconvenience of walking up a few hills.

The ability to climb hills (*without* pedal assistance or walking) is an important feature for any PEV. Many electric vehicles have motors sized to propel the vehicle and rider over flat ground, but are not often sized to swiftly move the vehicle up a hill. While the primary factor limiting range is the size of the batteries, the primary factors limiting hill-climbing ability is the size of the *motor* and the capacity of the *motor controller*.

So how much power (watts) is required for basic performance? To travel on flat ground at 20 miles per hour requires around 500 watts of power. Accelerating a 180 pound rider up a 10% incline from a complete stop can require *more than* 3500 watts. When evaluating the power of a PEV, look for a vehicle with peak power greater than what is necessary for your environment. When you consider your requirements for hill climbing performance, classify parking ramps, overpass inclines, sloped driveways, etc. as hills.

RULE OF THUMB

If you climb hills that require you to use second gear in your car, you will need a motor and controller capable of producing 1500 to 2000 watts for at least a few minutes. Peak outputs of more than 3000 watts are required for moving 200lb riders or more up even modest hills.

DETERMINE PEAK OUTPUT

_______ x _______ = _______

CONTROLLER OUTPUT (AMPS) | TTL BATTERY VOLTAGE | TOTAL WATTS

To calculate the peak power output of a motor, multiply the maximum controller output in amps by the voltage of the battery pack. (Both of these values should be available from the manufacturer's specifications.) For example, if a vehicle's controller produces 180 amps and it has a 24 volt battery pack, then the peak power output is 4,320 watts.

180 amps (controller output) x 24 volts (battery voltage) = 4,320 watts

Hill climbing ability is a good indicator of system reliability and durability because the entire system will be designed to transmit the motor's peak power to the road.

Battery Charging

The heart of any electric vehicle is the battery. The quality and design of the charging system (as well as the owner's charging habits) will determine whether or not your batteries will last for years or for weeks, and it may have a significant impact on the range you experience. A key point to remember here is: *charged batteries are happy batteries*. Therefore, a system that makes battery charging more convenient and quicker will lead to a longer range and a longer lifespan of the batteries.

The important characteristics of a charger are:

Is it on board, or does it need to be carried along by the user?
Generally, on-board chargers are more convenient, allow for more frequent charging, resulting in healthier batteries. External charges must be brought along when you want to recharge away from home.

Is the charger size appropriate for the size of the battery pack?
The larger the battery system, the higher capacity the charger should be. A charger should be rated in amps at *no less* than 1/7th of the battery pack's amp-hours. For example, a 34 amp-hour battery pack should have a charger capable of at least 4.8 amps. This will provide a charge time that is better than 7 hours (overnight charging).

RULE OF THUMB

Choosing a smart charger with a maximum output in amps that is 1/5th or 1/6th of the amp-hour rating of the battery pack will deliver 5 to 6 hour recharge times.

Is it a smart charger? The best charging systems for lead acid batteries in electric vehicles are 'smart' chargers which monitor the batteries' state of charge. A smart charger will change the charging profile as the battery charges, optimizing charging times *and* battery life and eliminating the chance of overcharging. Leaving a smart charger connected to the batteries for weeks or months will not harm the batteries.

While a smart charger can be left connected to the batteries indefinitely, a single stage charger does not have the ability to monitor the battery and so it is likely to undercharge a battery if left connected for short periods and will overcharge if left connected too long. Smart chargers safely recharge batteries more quickly than single stage chargers.

Some vehicles are capable of fast charging using a large external battery charger. Fast chargers may be offered as an option and are typically larger versions of the on-board chargers. To provide a fast charge (typically 1.5 to 2.5 hours) they need to be properly sized for the batteries to avoid overcharging and damaging the batteries.

Speed and Speed Control

A range of 20 miles at 20 miles per hour is the transition between recreation and transportation. On public roads, safety becomes an issue if you are unable to drive with the flow of traffic, so consumers shopping for PEV transportation should look for a vehicle capable of speeds of 20MPH or more. (Note: the classification of a PEV in many states may change if the vehicle maximum speed is *above* 25MPH.)

How you control your speed is also a very important consideration when choosing an electric vehicle. Electric motors can be controlled just like a light switch. They can be turned on and off with a simple switch, and speed can be modulated in the same way a dimmer switch controls the brightness of a light bulb.

RULE OF THUMB

If you are considering a PEV for transportation or errand-running on public roads, look for a vehicle with the power and speed to quickly move through intersections and drive with the flow of traffic.

In electric vehicles, the components that allow for smooth and precise speed control are the throttle (continuously variable) and a motor controller. In high quality vehicles, the controller is a computer. A quality, high capacity controller will allow the operator to drive very slowly and smoothly, and also accelerate and decelerate smoothly but with quick response.

When discussing speed control, the ability to *stop* is probably more important than the ability to go. An electric motor operated in reverse is a generator. That means that on an electric vehicle, there is the opportunity for the wheels to turn the motor and put electricity back into the battery. Some vehicles (especially those with computer controllers) can convert the momentum of the vehicle into energy to recharge the battery when the operator chooses to slow down. This is often referred to as *regenerative braking*. A vehicle with regenerative braking also has a built-in governor to limit maximum speed. This feature is especially important when driving down long hills.

Two benefits of regenerative breaking are *increased range* and *one-hand* speed control. Using the throttle to accelerate and to slow down makes speed control simple, intuitive, and responsive.

Personal Electric Vehicle Buyer's Checklist

Although each consumer will have personalized needs, the topics discussed in this guide should be considered when evaluating any Personal Electric Vehicle. There are many other attributes of electric vehicles that will become important purchase criteria as you refine your understanding of needs such as weather resistance and durability, cargo capacity, customization, and serviceability. To help you in your comparison, use the checklist summary below.

MODEL			
PEV name	Vehicle A:	Vehicle B:	Vehicle C:
Price			
ROAD LEGAL / SAFETY			
VIN for registration	YES NO	YES NO	YES NO
DOT headlight	YES NO	YES NO	YES NO
DOT taillight	YES NO	YES NO	YES NO
DOT tires and wheels	YES NO	YES NO	YES NO
Wheel size over 16"	YES NO	YES NO	YES NO
Low center of gravity	YES NO	YES NO	YES NO
One hand speed control	YES NO	YES NO	YES NO
Front and rear brakes	YES NO	YES NO	YES NO
Automatic braking	YES NO	YES NO	YES NO
RANGE AND POWER			
Battery capacity required: *(Calculate the vehicle's watt-hours using equation 1 on page 5.)*	Total watt-hours:	Total watt-hours:	Total watt-hours:
Your desired range in miles: *(Calculate the vehicle's estimated range using equation 2 on page 5.)*	Predicted range:	Predicted range:	Predicted range:
Maximum motor power in watts: *(Calculate the vehicle's peak output using the equation on page 6.)*	Peak power output:	Peak power output:	Peak power output:
SPEED AND FUNCTIONALITY			
Top speed, sufficient to be safe in traffic?	Top speed:	Top speed:	Top speed:
Carry enough cargo to be useful?	YES NO	YES NO	YES NO
Construction durable for the environment and typical use?	YES NO	YES NO	YES NO

NOTES