Electric Bicycles:
A Guide to the Market

Synopsis

Rapid technological and design gains have created a dramatically new state of the art for electric bicycles. This document describes the current state of the art, and provides one method to achieve a well-informed, long-term purchase of an electric bicycle.

This document emphasizes range, performance, and proven design.

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Contents

Introduction

Modern electric bicycles integrate many innovations from technology and design, particularly in the past year. These developments beckon for the attention of many consumers. The time is right—environmental and economic motivations favoring electric vehicles have never been greater, nor the choices so diverse, for so many people.

- Electric cyclists unfamiliar with latest developments have two reasons to look again.
- Millions of others have reason to investigate electric bicycles for the first time.

Why This Document?

This guide evaluates electric bicycle technology as it appears in the market. Certainly this guide is not the only industry synopsis available. Alternatives include the following:

- *Electric Bikes Worldwide Reports*—$300 US, covering corporate and business trends.
- *Electric Bicycles: A Guide to Design and Use*—$45 US, emphasizing design and use from IEEE perspective (pubblished 2005).
- *ExtraEnergy.org* evaluates electric bicycles, emphasizing European models.
- Refer also to *"Appendix B: Additional Resources" on page 48*.

ExtraEnergy sustains annual reports and product reviews that are free and freely available, but this is with an emphasis on European manufacturers. In the USA, notable online websites that track news and developments for light electric vehicles (LEVs) emphasize electric cars, and electric bicycles have never gotten the same publicity. In the meantime, community and regional newspapers have been multiplying articles about electric bicycles by an order of magnitude over this time last year.

This document illustrates the global interest in electric bicycles, but questions remain:

- How does a person shop for an electric bicycle when things are so dynamic?
- How can a person wade through countless articles to gain perspective?
- How to make a good long-term decision when buying the first electric bicycle?

This document is one response to these and additional questions.

NOTE: This guide began as a short holiday project, but became a seven-month immersion into the world of electric bicycles. This immersion continues.

The World Embraces Electric Bicycles

Electric bicycles, also known as e-bikes, e-bicycles, pedelecs, and power-assisted (bi)cycles, have attained a state of the art that was formerly unimaginable. The popularity of electric bicycles increases quickly on nearly every continent, in response to design and performance gains, and in response to larger economic or environmental concerns.

- For perspective, the article *Electric Bikes are Taking Off*, by Carolyn Wehlan of the International Herald Tribune, provided an optimistic snapshot as of March, 2007.
- 2008 will break Europe's 2007 record-setting sales.
  - *ExtraEnergy.org tracks rapid global and European developments.*
  - *Accell (Netherlands) has strong first quarter sales, driven by electric bicycles.*
  - *Revolutionizing Urban Transport—British Company penetrates the US market.*
- Asia has already realized an even greater level of implementation, to achieve critical mass with widely-deployed lead acid batteries and ensuing issues.
  - *Green Technology from China To the World.*
  - *China's Domestic Bicycle Sector Has Huge Potential.*
  - *Tube Investments of India, Limited, achieves top 10 status with electric bicycles.*
  - *40 Million Electric Bicycles Spark Environmental Dilemma in China.*
- The Americas see dramatic innovation, sales, and adoption levels.
  - *Electric Bicycle Sales Surge (Tampa Bay, Florida, USA).*
  - *Optibike, LLC Doubles Production (Boulder, Colorado, USA).*
  - *Ed Begley's Green Life (activistic promotion of electric bicycles).*
  - *Electric Bicycles Moving Fast (Chatham, Ontario, Canada).*
  - South America sees a great deal of activity, with *manufacturing in Brazil imminent*.
- Australia continues their innovation and adoption, but with recent legislative review of e-scooters, no longer considered as being electric bicycles, in legal definition.
  - *Electric Bicycle Companies in Australia*
  - *Private-party Manufacturer and Dealership List for Australia*
  - *On your bike: scooter law a bad joke*

The technology has begun to grow (dynamically) and to deliver on its potential. The public increasingly buys, writes, reports, and reads about electric bicycles.

However, one should exercise scrutiny and even skepticism if considering a purchase. A buyer should be selective, and obtain as much power as affordable. This perspective is repeated often by multiple parties in this industry.

Three Steps to Learn About Electric Bicycles

After reviewing the benefits from and consumer feedback about electric bicycles, the remainder of this document describes the state of the art, providing three general steps for achieving a well-investigated purchase of an electric bicycle:

1. **Surveying** the components of and benefits from the latest state of the art
2. **Strategizing** your personal priorities and cost factors
3. **Seeking** a worthy maker and the most power you can afford

Table 1 describes document organization and purposes.

Table 1: Document Organization and Purposes

Section	Purpose
"Introduction"	Introduces terms and very brief background information for this industry. Summarizes document organization and purposes.
"Step 1: Surveying State of the Art"	Establishes the foundations of due diligence in this technology. Briefly introduces multiple topics from technology.
"Step 2: Strategizing a Purchase Decision"	Summarizes the information commonly available to shoppers, and cites additional information and cost factors.
"Step 3: Seeking a Worthy Manufacturer"	Describes the value that a good company contributes to your purchase, and potential risks associated with settling for less. Lists some of the leading makers available in the market today.
"Appendix A: Glossary"	Describes a few frequent or ambiguous terms related to "e-bicycles."
"Appendix B: Additional Resources"	Links to various resources in support of e-bicycles and light electric vehicles (LEVs).
"Appendix C: Bicycle Type Questionnaire for Readers"	Five questions provide one method to identify the bicycle frame likely to be preferred by the reader. This questionnaire and analysis are focused on full-sized bicycle frames adapted to electric power assistance, not conventional bicycle frames as a whole.
"Appendix D: Light Electric Vehicles and the Environment"	Introduces and comments upon two topics: • Fossil-Fuel Dependence and Electricity Generation
"Afterword"	Offers closing comments.

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Benefits From and Consumer Concerns With Electric Bicycles

The motivations and the concerns of consumers with electric bicycles include these topics:

- *Health Benefits from Cycling*
- *Practicality Benefits from Power Assistance*
- *Economic and Environmental Benefits from Electric Bicycles*
- *Consumer Feedback About Prior-Generation Electric Bicycles*
- *Hope for the Present and Future*

Health Benefits from Cycling

Conventional cycling has long been known as one of the best methods possible for low-impact cardiovascular exercise. Power assistance adds no additional exertion to a rider than does conventional cycling, and retains the option to pedal. The following articles are a few resources that describe the health and fitness gains derived from regular cycling:

- Bicycle Man's "*Bicycling Health & Fitness*"
- Bicycle Victoria's "*Health Benefits of Cycling*"
- Rick Price's "*The Health Benefits of Cycling*"
- Current Google results for "*Health Benefits of Cycling*"

Practicality Benefits from Power Assistance

Adding electric power to a bicycle can help guarantee multiple benefits of cycling and greatly increase usability. Electric bicycles enable a better use of time, additional energy for longer distances at greater speed, and perhaps some extra power for additional cargo.

- Greater speed and range enable an electric bicycle to address multiple needs at one time (combining time-sensitive commuting with exercise, for example).
- The additional power permits the ability to transport (or towing of) more cargo.
- Good design enables a rider to work up a sweat, or to stay dry and fresh, depending on his or her desires for each particular trip.
- The thrill and handling of a good design and great performance increases motivation to use a bicycle. Electric drive can add some real fun to the experience of a bicycle.

Economic and Environmental Benefits from Electric Bicycles

A major reason for the explosive popularity of electric bicycles is, of course, the economy. The increases in fuel prices increase people's interest when battery technology and electric drive have achieved important gains. Electric bicycles have reached a strategically important state of the art at the best possible time.

Aside from avoiding expensive gas bills, riders wish to spend less time commuting, or to combine commute times with exercise. Furthermore, electric bicycles achieve some positive environmental impact over the alternatives:

- Reduce vehicular gas emissions.
- Consume less raw materials on a per-unit basis to manufacture.
- Increasingly, every component of an electric bicycle, including the battery (-ies), can be made, recycled, or otherwise processed with lesser environmental impact.

However, certain considerations or questions remain to be resolved in the present day.

- For those interested in the generation of electricity itself, refer to "Fossil-Fuel Dependence and Electricity Generation" on page 53.
- For current issues with lead battery disposal, in an economy comprised of 40+ million owners/riders of electric bicycles, see the latest developments in China.
  - *40 Million Electric Bicycles Spark Environmental Dilemma in China*

Consumer Feedback About Prior-Generation Electric Bicycles

Any objective synopsis of this industry must address the likes and the displeasures reported by consumers. Ample raw data remains available for anyone to review, with or without Consumer Reports™ (and currently, it is without Consumer Reports™, but there is European equivalent in *ExtraEnergy.org*).

Many or most of the reported issues with e-bicycles pertain to cycles older than two years. Manufacturers have been listening to consumers, and to their own successes, with much work to innovate over the past two years. The current "phase" of electric bicycle adoption started, arguably, sometime in early 2007, and it was a global phenomenon—still is.

NOTE: It is no coincidence that several high-end electric bicycle models have appeared in the past 12 months, particularly in the North American and European markets. These and additional cycles are listed in *"Notable Electric Bicycle Makers Supporting 250 Watts or More" on page 40*.

A few perceived shortcomings include the limitations imposed by cycling of any nature:

- Temperature, rain and snow are major factors, to imply the need for specialized rain clothing, and a willingness to "brave the elements" with snow tires on a regular basis.
- Parking can sometimes be inadequate for stowing any kind of bicycle in public.
- Many people (in fact, the majority) perceive a need for a vehicle that can carry multiple passengers on short notice, and bicycles of any nature are often too limited.

NOTE: This is not to say that such issues have not been resolved to the satisfaction of many riders. Rather, this is a list of commonly voiced concerns, resolved or not.

Those riders who have experience with the prior-generation of electric bicycles have voiced more specific concerns to include the following:

- Issues with extremely short range and battery lifetime were voiced about the *E-Bike 36*.
- Prior range limitations failed to addressed frequent needs.
- Uphill performance was weak or entirely non-existent, and this gripe encompassed more than one motor or drivetrain type.
- Relative to other types, lead-acid batteries have less-than-ideal characteristics which include temperamental recharge demands, reduced charge cycles, and low (or lowest) energy/density ratios. Environmental concerns also arise.
- Less-than-waterproof integrity can create risk of electric shock.
- Manufacturers have not always made it easy to find replacement batteries, and an owner may have to consider buying replacement parts in preemptive fashion before a particular model is discontinued.

A few present-day concerns may remain for ongoing consumers of electric bicycles:

- Some manufacturers have not stated electrical specifications in accurate fashion.
- Non-chain shaft drive has received mixed reviews, at best, but it is still new a newer type of transmission, as is belt drive.
- Customer support issues can arise when an electric bicycle is purchased at a major retail chain, instead of purchasing from a specialized dealer or manufacturer.
- Hub-mounted motors (disk and non-disk) are widely available for turnkey electric bicycles or conversion kits, and the makers continue to support the concept. However, hub-mounted motors have received certain criticisms. These factors are addressed further in *"Motors and Power Integration" on page 22*.

Hope for the Present and Future

It can be demonstrated with ease that not every manufacturer, dealership or electric bicycle model been a success story. The very same thing can be said of laptop computers. Many of the issues cited above can be avoided, and further benefits can be obtained, if a buyer knows what to seek, where to find it, and how to account for true costs and trends.

Even with cautionary tales, a record-setting number of riders embrace the latest of electric bicycles, propelled by lessened oil-dependence and lessened greenhouse gas emissions. This guide provides status, structure and strategy for what is a new technology to many.

Step 1: Surveying State of the Art

Introduction

We have a new state of the art for electric bicycles. This section surveys the components in e-bicycle design and technology, and summarizes general status and guidelines for each.

NOTE: These topics provide an outline of what to think about when evaluating any electric bicycle as a potential purchase. Most of these topics are adapted further into *"Step 2: Strategizing a Purchase Decision" on page 33*.

Types of Electric Bicycles

There are several types of electric bicycles, and the classification gets complex. This section describes common types of e-bicycles, with additional light electric vehicles (LEVs) that are marketed alongside of them:

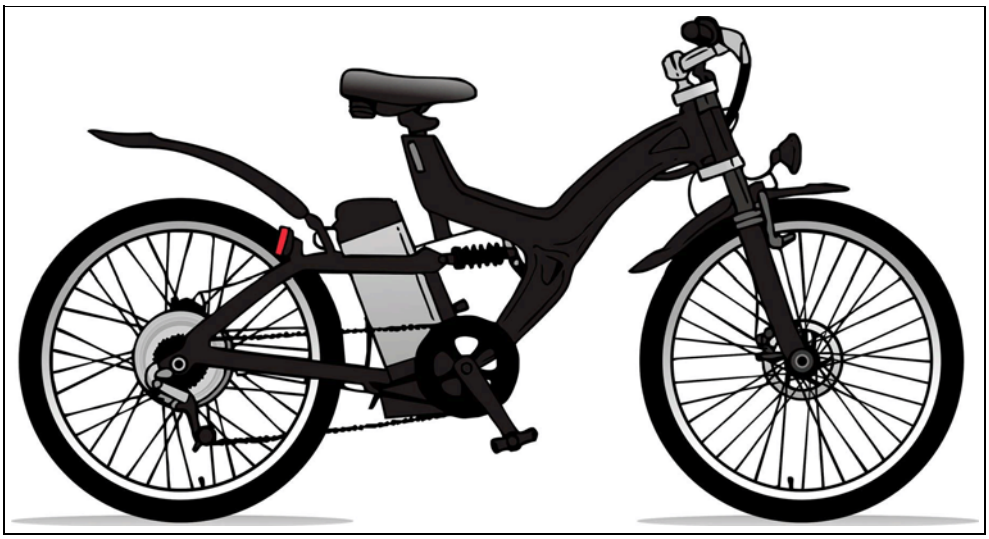
- *Mountain, Sport, and Sport-Hybrid Bicycles*
- *Urban, Urban Hybrid, and Utility Bicycles*
- *Cruiser Bicycles*
- *Compact & Compact Folding Bicycles*
- *Electric Scooters and Electric Mopeds*
- *Monocoque Frames for Electric Bicycles*
- *Other Light Electric Vehicles*

For a list of current electric bicycle makers and models, refer to the section *"Notable Electric Bicycle Makers Supporting 250 Watts or More" on page 40*. For a questionnaire about the type you might prefer, refer to *"Appendix C: Bicycle Type Questionnaire for Readers" on page 51*.

Mountain, Sport, and Sport-Hybrid Bicycles

This can be the most rugged electric bicycle type, and can be the most recognizable.

Figure 1: One Appearance of an Electric Sport Bicycle



This type of e-bicycle has the following general characteristics:

- Forwarding-leaning posture for the rider is nearly always the norm, with straight or relatively straight-across handlebars.
- Performance seats are often favored over wider seats, but wider seats can work well.

- Full-sized or nearly full-sized wheels are the most common. Default tires are often full-width with knobby treads; sleek street tires are available.
- Front or rear shock absorption increases the cost, but can help protect electronics.

The following are examples of electric sport bicycles; citation does not imply endorsement:

- *Liberty Stealth Series Electric Bicycles*
- *Ohm Sport XS700 and XS750 Sport Bicycles*—performance sport "hybrid" models
- *Rayos electric all-terrain bike*—replaces the recently discontinued ElecTrec and Lashout
- *Titanium Flat Road EB electric bicycle*—street-oriented sport e-bicycle
- *Urban Mover UM36 UGlider™*—a sportish "hybrid" more like a mountain bike

Urban, Urban Hybrid, and Utility Bicycles

This is a diverse class of full-sized bicycle type that emphasizes versatility.

Figure 2: One Appearance of an Urban Hybrid

This type of e-bicycle has the following general characteristics:

- The rider generally sits straight up or slightly forward.
- This type supports a wide variety of seats, racks, and cargo accessories, options for step-through frames; robust electrical power options.

Some models in this category boast some of the highest advertised ranges. These would be a few of the more typical examples; citation does not imply endorsement:

- *EcoBike Elegance*
- *ElecTrek Electric Police Bicycle*—hybrid with full dynamic suspension
- *Ezee Forte 8* and *Ezee Sprint*
- *Giant Bicycles Twist Freedom DX*
- *Schwinn's 2008 Electric Bicycle Series*
- *Urban Mover UM44 USprite™*

Cruiser Bicycles

This traditional type of bicycle has a more laid-back physical posture than sport cycles, urban cycles, and hybrid designs as well.

Figure 3: One Appearance of A Cruiser Electric Bicycle

The cruiser or beach cruiser is easily recognizable, even with electric bicycles.

- Wheels are typically full-sized or close to full-sized, and tires can be very large.
- Handlebars almost invariably reach rearward so the rider can sit upright or lounge.
- Wide, leisurely seats are common.
- Step-through cruiser frames are available.
- There is rarely moving suspension or shock absorption.
- You may see elongation of the cruiser frame compared to others.

It is entertaining to watch, but in the past three months, perhaps especially in the past month, a great number of dealerships and manufacturers have increased their citation of "cruisers." Manufacturers have increased substantially their "cruiser" models in 2008. Cruiser popularity has always been established, but electrical power adds a great deal of range and ease of use to a very comfortable type of bicycle.

The following are examples of cruiser-looking electric bicycles, but citation does not imply endorsement.

- *Algardi Electric Cruisers and Compact Electric Bicycle*
- *Biria BionX Electric Cruiser*
- *Ezee Cadence Cruiser*
- *ZAP Electric Bike SX* —perhaps classifiable as a cruiser hybrid

Compact & Compact Folding Bicycles

Compact electric bicycle frames, whether they fold or do not, can be some of the most diverse, light-weight, and easily-handled electric bicycles on the market.

Gains in battery technology and gearing can offer the promise of usable performance and range. These e-bicycles make no apology for being small, nor do they need to do so, in most cases. Even state-of-the-art suspension has become available. Range is ever increasing. Seek uphill performance (as with any category of e-bicycle, for that matter).

Figure 4: One Appearance of A Compact Electric Bicycle

This diverse category of electric bicycle frame typically has features as follows:

- The tires and wheels are often a smaller diameter than with more traditional frames.
- Seating posture is typically straight upright, with shorter wheel-base length.
- Not all compact electric bicycles fold, but folding is found often in the compact class.
- Technology gains have increased range and power with lesser weight, with shock absorption available.

These would be merely a few examples of compact electric and folding bicycles, but citation does not imply endorsement:

- *Ezee Chopper* —non-folding
- *Ultra Motor A2B Compact* —non-folding (*click here for blogger-oriented discussion*)
- *Algardi Miki Electric Bicycle* —folding
- *BionX Folding Compact Electric Bicycles* —folding
- *EcoBike Vatavio Folding Compact Electric Bicycle* —(multi)folding
- *Ezee Quando Folder* —folding
- *Urban Mover UM24 UTerrain™*—a folding e-bicycle with 20” wheels

Electric Scooters and Electric Mopeds

"Electric bicycles" of this type are sometimes more like an electric pedaled moped, other times more like a Vespa-looking scooter with or without pedals, and they often offer good range and speeds. However, a "scooter" can also be an electric cart for personal mobility, or a skateboard-like vehicle with small handlebars. Electric scooters are the most legislatively active realm of electric bicycles, at the present time. More than one jurisdiction has struggled with how to define them. Some vehicles in this class as large as gasoline-powered equivalents.

People still call these electric bicycles or e-bikes on a frequent basis. Electric bicycles of this class are suddenly very popular. Countless articles have appeared in the past six months, sales generally are booming, and inventories are often back ordered. They can (mostly) be defined as having these characteristics:

- No license required.
- May or may not have pedals.
- More often than not they have a floorboard or central footrest and step-through frame.

The following articles and models are merely a few examples of a diverse category.

- *The 7 Best Electric Scooters: From Prototypes to Production Models*—Michael Graham Richard, contributor to Treehugger.com, June 30, 2008
- *E-Bikes Fight the Power*—Toronto Sun, Canada, June 26, 2008
- *On your bike: scooter law a bad joke*
- *Sample Inventory and Advisories from an Ebicycle Dealership* (Sarnia, Ontario, Canada)
- *Volt Canada's Dream Ryder*
- *X-Treme Scooters' XB-508 Electric Moped*
- *Zap offers three models of "electric scooter,"* but two of them are very small in size.
- An "electric scooter" can be a three-wheeled or a four-wheeled electric cart that aids in personal mobility: *Sample inventory and model selection for "electric mobility scooters"*
- A "electric scooter" can be a very small electric vehicle unlike any of these above definitions, and perhaps more like a skateboard with handles: *The X-Treme 250 Scooter*

Monocoque Frames for Electric Bicycles

A few specific electric bicycles have been created with a full or partial monocoque frame. Monocoque is the French word for "shell." With a complete monocoque frame, the metallic shell houses and protects the motor or the battery(-ies), or both of these components and more. Some electric bicycles use a partial monocoque frame, in which the battery is housed within the frame, but the motor appears outside of the frame.

Monocoque frames can make an electric bicycle appear more streamlined or unique. Monocoque frames enable a maker to achieve uniqueness in structural design that cannot be duplicated by anyone else without patent infringement.

Every maker that uses monocoque design presents a compelling case as to its advantages. It could be reasoned that a monocoque frame inherently possesses greater waterproof integrity than electric modules (boxes) on conventional design. Full monocoque frames can be more expensive to produce, and typically they require robust engineering.

These would be a few examples of monocoque frame designs in the market:

- *Optibike implements a full and unique monocoque frame for world-famous mountain bicycles.*
- *The Electrobike Pi™ implements a patented monocoque frame unlike any other.*
- *iZip implements a partial monocoque frame for multiple electric bicycle models.*

Other Light Electric Vehicles

Many additional light electric vehicles can offer electric power assistance without requiring an operator license. This topic summarizes the less conventional light electric vehicles that are smaller than electric automobiles or electric golf carts.

NOTE: As with nearly any topic in this document, any set of external references could be increased in size (sometimes tenfold). This topic and the associated references are not comprehensive.

Recumbent electric bicycles are increasingly available, and after-market motor conversion kits are available for installation on conventional recumbent bicycles:

- *Ecospeed*—supporting conversion kits and information for recumbent electric bicycles
- *BionX*—the best-known electric conversion kit supporting recumbent electric bicycles
- *E-4 Electric Mid-Drive*—another motor conversion kit for recumbent electric bicycles
- *Recumbent Review*—a blogger-oriented investigation into recumbent bicycles and tandem bicycles, with emphasis on integration of electric power assistance

Tandem electric bicycles provide seating for two, with electric power assistance often managed by the rider in front. This would be one example:

- *Tandem electric mountain bicycle* with Currie electric conversion kit already installed
- *Nameless tandem electric beach cruiser* offered by Electric-bikes.com

Electric tricycles are often presented alongside electric bicycles. These would be two examples:

- *Velomobiles*—recumbent electric tricycles with enclosed farings
- *Lightfoot Cycles*—a diverse selection of recumbent bicycles and tricycles, most of which can be converted to electric power assistance

Four-wheeled electric carts with bicycle-style wheels typically qualify for operation without a license, presuming that top speed remains the same (roughly 20 MPH or 30 KPH maximum):

- *Rhodes Car - 4 Wheel Bike that Rides Like A Car*

Electric all-terrain vehicles (ATVs) have hit the market, and these are merely two:

- *HOMO AE4 Electric ATV*
- *Two electric ATVs* by Zap

Electric go-carts are as obvious in their potential for electric power as any LEV:

- *Razor Ground Force electric go cart*

Electric motorcycles of full size, and that require an operator license, are increasingly available and expected to increase in popularity, worldwide:

- *Enertia Electric Motorcycle*
- *ErockIT GmbH Hybrid-Electric Motorcycle*
- *Vectrix ZEV Electric Motorcycle* and *Consumer Reports' independent review*
- *Zero Motorcycles* and *ENN's independent review*
- *Electric motorcycles will become the largest selling type of motorcycle in China.*

Some light electric vehicles defy any category. These would be a few examples:

- *The Segway* is the most widely-known example of a unique LEV.
- *The developing Uno* vaguely resembles a motorcycle and a unicycle, without being either of them, or anything else, for that matter.
- *Non-pedaled Tandem Electric Bicycle* - It sure looks fun, but is it a bicycle if it has no pedals and has four wheels? *Click for additional article.*

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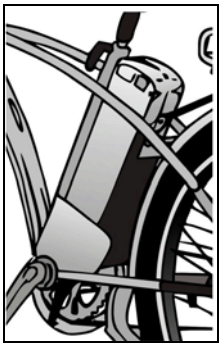
Battery Technology



A good percentage of the leading manufacturers offer nickel-cadmium (NiCD), nickel-metal hydride (NiMH), or Lithium-Ion (Li-Ion) batteries for electric bicycles. Several manufacturers continue to offer sealed lead-acid (SLA) batteries. Gains for any type of battery are likely possible because of sustained research and development in all facets, although lead clearly has some hurdles to overcome.

A battery type must be chosen with scrutiny. Buying an electric bicycle and then storing it in a closet or garage for a prolonged period of time can have negative repercussions to the life of the battery.

Some batteries are guaranteed, and others are not.

Getting The Lead Out?

Lead-acid battery technology has been one liability of electric bicycles in the past, at least in part. However, this is the battery type that made electric bicycles possible in their numbers thus far, being the least expensive battery option for millions of riders.

Few, if any, would dispute that lead has always entailed limitations and environmental factors. The advantages and disadvantages are further cited in *Table 2*.

It is possible that lead-acid battery technology can overcome some hurdles, but current issues remain. Consider the environmental crisis created by 40 million riders of electric bicycles in China, most of which have invested in lead-acid technology, given the relatively low cost:

- *40 Million Electric Bikes Spark Environmental Dilemma in China*

Availability, recycling and "green" manufacturing will likely increase for all battery types, regardless of what China does in response to its lead battery crisis.

Lead-Acid, Li-Ion, NiCD, and NiMH

Table 2 summarizes the advantages and disadvantages of the four battery technologies that support electric bicycles. This summary is subject to variables by manufacturer, battery design, and roll-out (availability) that can change on a monthly basis. Countless volumes of research support this technology. Every battery type below has several manifestations in the market of electric bicycles.

Table 2: Summary Chart of Battery Technology[a]

Battery Type	Advantages or Design Dynamics	Disadvantages
Lead-Acid (sealed)	• Inexpensive and simple to manufacture. • Mature, reliable and well-known technology. • Low self-discharge —the self-discharge rate is among the lowest in rechargeable batteries. • Low maintenance requirements — no memory; no electrolyte to fill. • Capable of high discharge rates.	• Not to be stored in a discharged condition. • Low energy density — poor weight-to-energy density. • Environmentally unfriendly — the electrolyte and the lead content can cause environmental damage.
Lithium-Ion	• Highest energy density to weight ratio. • Eliminates need for periodic care for a long life. • Has no memory effect. • Achieves a better cost-performance ratio for battery packs in series than for single cell. • Is arguably better for the environment, from a raw materials viewpoint, to other options. • Li-ion-Cobalt is the most developed Li-ion technology, with flexible shape options.	• All lithium-ion technologies require a protection circuit to prevent overheating. • Aging can depend on storage conditions (best stored at a 30% loaded state). • Can damage easily by over(dis)charge.
NiCD	• Fast and simple charge — even after prolonged storage. • High number of charge/discharge cycles — if properly maintained. • Good load performance — the NiCd allows recharging at low temperatures. • Long shelf life – in any state-of-charge. • Forgiving if abused — the NiCd is one of the most rugged rechargeable batteries. • Economically priced — the NiCd is the lowest cost battery in terms of cost per cycle. • Available in a wide range of sizes and performance options.	• Relatively low energy density — compared with newer systems. • Memory effect — the NiCd must periodically be exercised to prevent memory. • Environmentally unfriendly — the NiCd contains toxic metals. • Some countries are limiting the use of the NiCd battery. • Has relatively high self-discharge — needs recharging after storage.
NiMH	• 30%-40% higher capacity over a standard NiCd. The NiMH has potential for yet higher energy densities. • Less prone to memory than the NiCd. Periodic exercise cycles are required less often. • Environmentally friendly — contains only mild toxins; profitable for recycling. • NiMH generates more heat during charge and requires a longer charge time than the NiCd. • About 20% more expensive than NiCd	• Limited service life — shallow rather than deep discharge cycles preferred. • Repeated discharges with high load currents reduce the battery's cycle life. • High self-discharge — NiMH has about 50% less stored shelf life than NiCd. • Performance degrades if stored at elevated temperatures. • High maintenance—requires regular full discharge to prevent crystalline formation.

a. This summary chart is an adaptation and consolidation of information that is available from multiple resources. The following specific resources contributed to this specific summary:

- *MSC Vertriebs GmbH*, global distributor of high-technology electronic components
- *Advantages and Disadvantages of the (Sealed) Lead Acid Battery*, by Prof. Ilga Jurkelo
- *Advantages and Disadvantages of the Nickel Cadmium (NiCD) Battery*, ibid
- *Advantages and Disadvantages of the Nickel Metal Hydride (NiMH) Battery*, ibid

The following are additional factors for one or more of the above battery types:

- "In terms of disposal, the sealed lead acid (SLA) is less harmful than the NiCd battery, but the high lead content makes the SLA environmentally unfriendly. Ninety percent of lead acid-based batteries are being recycled." —Professor Ilga Jurkelo
- At least one spokesperson for the battery industry has presented a case that both NiMH and Li-Ion batteries will remain the most desirable and in-demand battery technologies for the foreseeable future.
  - *EV World's Advanced Battery Market Review*
- Some batteries are guaranteed, and many are not. Seek the battery type that offers the behaviors best suited to your cycle use, and seek a warranty whenever possible.
- The superior Lithium Ion (Li-ion) technology has come of age as a leading battery technology for consumer electronics, electric vehicles, and aerospace applications.

Lithium-Ion-Cobalt batteries, the most establish version of the Li-Ion battery type, achieve the following advantages over the older battery technologies:

- compact dimensions with the highest available energy density
- longer life cycle
- absence of memory effect, thus sustaining a battery's lifetime and performance
- more environmentally friendly materials than alternatives

Li-ion can often be the superior battery technology, and Lithium-Ion-Cobalt is often the most established Li-ion choice, particularly in vehicular applications. Seek this battery type whenever possible, but regardless of the battery type chosen, seek out a guarantee.

If storage is going to be a factor for you, even for a few months, examine potential impact to your battery performance before making a purchase, if possible.

For additional cost factors, refer to *"Replacement Battery and Lifetime Recharges" on page 37*.

Calculating Range from Amperage and Voltage

Can you trust the amperage and wattage figures cited by the makers of electric bicycles? Is there a way to verify their range? Consider a recent advisory from Electric Vehicle World in relation to electric bicycles and scooters:

> "Two words of advice: (First), don't trust the wattage numbers proffered by many Asian clone scooter makers - they are usually grossly over-inflated. Second, buy as much amperage and wattage as you can afford. You won't be disappointed."
>
> Source: EV World's *Electric Scooter/Cycle Guide*

This document presents one formula and one general rule by which to establish the approximate range of an electric bicycle. If you know the *amperage* and the *voltage*, you can calculate the approximate range, and compare your figure against advertised range.

1. To start, use this formula:
   - **Amp hours (Ah) x Volts (V) = Watt hours (Wh)**
2. Refer to the following three parameters for how Watt hours roughly relate to range:
   - You require 240 Wh to have a range of roughly 18 miles (29 km).
   - You require 480 Wh to have a range of roughly 36 miles (58 km).
   - You require 720 Wh to have a range of roughly 54 miles (87 km).

NOTE: Electric bicycles are often restricted to a speed of 20 MPH or 30 KPH, across level ground. A greater wattage increases the range, and can increase the uphill torque, but it typically will not increase the maximum speed, which is restricted.

As an example, apply this approach to one hypothetically-advertised e-bicycle:

- Advertised battery specifications: 10Ah x 24V(produces a result of 240Wh)
- Advertised range: 60 miles

The advertised range above cannot be accurate if the Ah and V figures reported above are accurate. The battery amperage and voltage above would only support a range of 18 miles (29 km) instead of the 60 miles (96 km) advertised.

3. If an e-bicycle's advertised range does not generally match the amperage and voltage (Watt hours), which are standard specifications for any e-bicycle, then you should establish the reason why before making a purchase. Refer to *"Integrated and Auxiliary Electronics" on page 28* for battery charge monitoring and range calculation tools.

Lifetime Recharges and Disposal

Lifetime recharges are an estimated figure. This figure is the number of complete recharges for a given battery or battery pack for its lifetime. Usage patterns and long-term storage can affect what a buyer actually experiences.

The battery or battery pack can be one of the most expensive components when buying a new electric bicycle (or converting a conventional bicycle to electric). One long-term ownership consideration pertains to when you will have to replace it.

General guidelines in choosing your initial battery or in upgrading would be as follows:

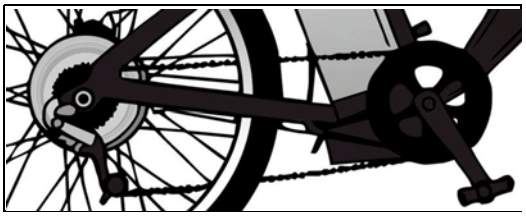
- Seek a guarantee for your battery, regardless of its type, so that your lifetime recharges, and ensuing replacement costs down the road, can be established with some degree of precision and predictability.
- It is not known if current legislation for battery disposal will become more strict.
- Superior battery technology produces superior battery performance, at a higher price.

Refer to these topics for additional information:

- *Replacement Battery and Lifetime Recharges*
- *Step 3: Seeking a Worthy Manufacturer*

Motors and Power Integration

This section describes the following components of electric bicycles that relate to power:



- *Power Control*
- *Efficiency Modes*
- *Motors and Drivetrains*
- *Gears and Efficiency*
- *Semi-Automatic Transmissions*
- *Battery and Motor Location*
- *Motor Conversion Kits*

Power Control

There are many ways to categorize e-bicycles. They can be grouped according to frame type, drivetrain or transmission type, size class, riding application, wattage class, battery type, country of origin, and so forth. However, there are three primary types of power control to cover all classes of e-bicycles. Power control refers to the method by which a rider manages electric power—by hand, by foot, or both.

- **Manual or throttle control**—This type of power control or hand regulator can vary greatly from design to design, but in this approach, the electric power is controlled by hand or by thumb, and remains independent of whether a rider is pedaling.

  This method can sometimes be known (particularly in Europe) as “E-bike” control, named after the EV Global Motors E-Bike™ line of electric bicycles in Asia, which followed the Western preference for a throttle. Otherwise, in North America, an “e-bike” typically refers to any type of electric bicycle, regardless of control type.

- **Pedal activation (pedelec)**—Advanced electronics and multiple sensors support a very different method to control power on an electric bicycle. This method uses the pedals to implement power assistance.
  - Pedal hard to go fast and the bicycle adds a greater amount of electrical power.
  - Pedal easy to go slow or sustain an easier speed and the power level does the same.
  - To coast or slow down, the rider does not pedal at all, and the e-bicycle responds with no electric power.

  This is known as the "pedelec" power control method, short for pedal-electric, and is the most popular method in Europe, where the term *pedelec* originated.
- **Hybrid power control**—This method is a combination of "e-bike" and "pedelec" power control methods, combining manual and foot control. Details and use may vary significantly from design to design.

Efficiency Modes

Many electric bicycles support two or three *modes* of efficiency.

- **Economy mode** optimizes range and sustains the battery charge for a significantly longer period of time, but at the cost of torque, acceleration, and perhaps uphill or offroad performance.
- The opposite mode is often called **Sport mode, power mode, performance mode,** or an equivalent. This setting enables high-performance acceleration, torque, more cargo-carrying capacity, or uphill performance. The trade-off is that range is reduced.
- A **Normal mode** is available on some models as a compromise between these two. The recently released *Giant Twist Freedom* is one e-bicycle that has three modes.

Motors and Drivetrains

Electric DC motors vary a great deal in how they are mounted to a bicycle and in how they apply power. Some riders can be very committed to one type of design.

- Avoid discontinued electric bicycles or conversion kits.
- Seek out motor designs (and makers) that remain in widespread use and popularity.
- A shopper should seek a warranty, regardless of the powertrain type chosen.

NOTE: Ongoing user discussions and manufacturer information far exceed the limited summary below, but this is a starting point.

The following powertrain and motor types have multiple examples in the market today.

- ***Belt-Drive Transmission***—This type of drivetrain continues on the market, perhaps being most available with compact electric scooters. A specially designed motor is mounted low in the frame, and drives the rear wheel by use of a belt. A rider might be able to sustain prolonged user of the pedals, but consumer feedback is largely pending.
- ***Direct drive* (*in-line chain-drive)*—**This method has the motor working with the primary bicycle chain—the same chain that the rider uses when pedaling. A great deal of innovation can happen with a "conventional" chain drive. Gearing for the motor varies with each specific manufacturer.
- ***Frame-mounted motor with dedicated chain drive***—Another common method is to mount a motor to the bicycle frame near the hub of the rear wheel, often on one side. The motor has its own small chain that drives a planetary gear on the rear wheel. This specialized chain is separate from the primary bicycle chain that remains in use with the bicycle pedals. Gearing remains specific to the manufacturer or aftermarket motor conversion kit.
- ***Wheel-mounted disk motor***—Many people call this a "hub" motor, but it can be distinct from the other type of "hub" motor. This is a ***pancake or dish plate motor***, sometimes even called a "frisbee motor," installed on one or both wheels. These motors can be placed on both wheels, effectively doubling the power available to the rider. However, these motors increase weight and centrifugal force on wheel(s).
- ***Hub motor***—Ideally, the term "hub motor" refers to a motor that replaces the hub of a wheel. Sometimes this can be a flat disk motor, other times it is not a disk motor. In either case, the motor itself is the hub—instead of being mounted beside it or near it.
- ***Friction-drive***—This type of electric drive installs the motor very close to one wheel. A shaft extends out from the motor, and this rotating shaft drives the wheel by spinning in direct contact with it. The motor does not interact with the chain. Multiple gears for the motor are rarely supported.
- ***Geared transmission-style shaft drive***—This type of electric drive is like a shaft-driven motorcycle. There is no chain anywhere on the cycle. The motor and the pedals apply power to a sealed and protected shaft that has bevel gears in front and back. Multiple gears (speeds) are supported.

NOTE: Every motor and drivetrain type cited above has additional manufacturers and models cited in the section *"Notable Electric Bicycle Makers Supporting 250 Watts or More" on page 40*. Citation does not necessarily imply endorsement.

Table 3: Summary Chart of Drivetrain Types

Powertrain Type	Advantages	Disadvantages	Examples
Belt-Drive Transmission	• Allows for a great deal of customization in design. • Silent operation. • Has received product review by the industry.	• Might reduce the performance of pedaling when motor is not used. • Limited customer feedback thus far.	• *eGo Cycle SE*
Direct Drive (Conventional in-line chain)	• No additional chain needed. • Monocoque frames can hide the motor with great protection. • The motor might inherit as many gears as are available to the rider. • Low center of gravity likely.	• Perceived (standard) drag upon the chain. • Chain remains visible, perhaps vulnerable to dirt. • Potential for noise alleged by critics.	• *Charger* • *Cyclone (Taiwan)* • *Electrobike Pi* • *Optibike*
Frame-mounted motor with dedicated chain	• A dedicated chain can attain good power transfer without complications. • Low center of gravity likely.	• A second chain and planetary gear are required. • Multiple gears for the motor may or may not be available. • Potential for noise alleged.	• *Charger* • *Rayos (ElecTrec)*
Wheel-mounted disk motor (pancake motor)	• Sometimes heralded by devotees as the most efficient approach, but not without rational disagreement. • No planetary gears or spinning shafts are needed for power. • Retains good protection from elements.	• Places a great deal of weight in the wheels, with potential handling issues at higher speed. • Uphill performance is at least a partial criticism of some models. • Multiple gears for the motor may or may not be present.	• *Additional Disk Motor Examples* • *BionX* • *Tidal Force (discontinued)* • *Golden Motor*
Hub-Motor (non-disk)	• No interaction with the primary bicycle chain required. • No additional transmission required.	• Adds weight to the wheel. • Torque factors can enter operational considerations. • Unsprung weight or mass.	• *Giant Twist Freedom DX*
Friction-based shaft drive	• Inexpensive. • Easy to mount. • By far the most mechanically simple concept.	• Inefficient—no gearing. • Friction wears out tires. • Pressure against the shaft might strain motor functions over time. • Motor must sustain very high RPMs at higher cycle speeds.	• *ZAP SX* • *Electric Bike Factory*
Geared shaft transmission	• Multiple gears are common. • No chain anywhere on the cycle. • Sealed installation prevents dirt from getting into it. • There is precedent in the motorcycle market.	• A relatively unfamiliar approach for cyclists. • Changing tires and reinstalling the wheel may become more demanding than with other methods.	• *Schwinn Continental*

Gears and Efficiency

Not all electric bicycles offer multiple gears within the electric motor. In such cases, a single gear for the motor reduces efficiency, particularly when climbing hills. Changeable gears make hill climbing easier, and extend the life and performance of your motor.

A single gear on a car would make good hill climbing and efficient top speeds impossible. It is possible to add more power to the motor when climbing hills and accelerating, but this is alone not an efficient approach.

A single-speed gear can require you to carry heavier and possibly a more expensive battery or set of batteries. Also, overloading an electric motor creates heat, which is wasted energy that can harm electronics and motors, and decrease the life of the product.

Having gears for the motor supports better performance, creates greater efficiency, and provides a longer life for the product.

Semi-Automatic Transmissions

Automatic or semi-automatic transmissions have been a marketed feature of the conventional bicycle market for years, although they might not be mainstream in comparison to manual gear control.

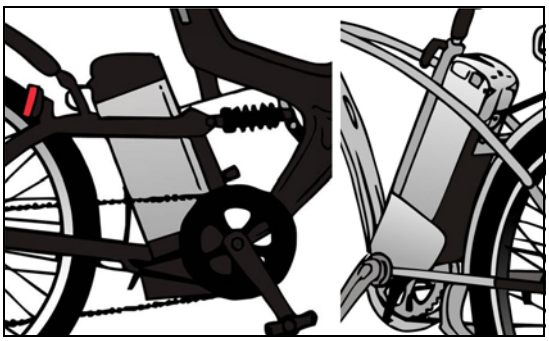
This would be one of several potential examples of such a transmission in the conventional bicycle market:

- *Trek Lime Bicycle ... Has Electronic Automatic Transmission*

The Electrobike Pi is perhaps the highest-end electric bicycle on the market to incorporate a semi-automatic transmission with electric power assistance. They do so with a patented monocoque frame unlike any other.

- *Pi Electric Bicycle with Semi-Automatic 8-Speed Transmission*
  http://www.tuvie.com/pi-electric-bicycle-with-semi-automatic-8-speed-transmission

Battery and Motor Location



This aspect of design remains open to explorative variation. Many designers place the battery and the motor as low as possible to achieve the lowest center of gravity. Another approach is to use two batteries for the e-bicycle, and placing one of them on a rack behind the rider's seat. Even this approach respects the advantages to be gained with a lower center of gravity.

If you are in a vehicle with heavy wheels (hub motor and battery in wheel, and so forth), the ride becomes rough with inferior handling. It is a well-known principle within auto racing and non-motored bicycle racing that light wheels increase performance and improve handling characteristics. The same principle applies to electric bicycles. A low center of gravity is the foundation of countless patents and articles that discuss design.

Motor Conversion Kits

A percentage of owners insist that motor conversion kits are the least expensive and most practical means to create an electric bicycle from a conventional cycle. Practitioners can often demonstrate that it is not a complex proposition. However, the motor kits can vary significantly in design and in quality. Not all kits that were available in 2006 may be currently available.

These would be a few examples of motor conversion kits. These examples are not comprehensive, and these examples are subject to the potential issues cited elsewhere in this document, to include motor location, gearing for the motor, and other factors.

- *Bicycle-Power.com*—One superior listing of conversion kit manufacturers, worldwide
- *Are you crazy if you electrify your bike?*
- *BionX Electric Bike Conversion Systems*
- *Currie Technologies Electric Bicycles and Motor Conversion Kits*
- *Ecospeed*
- *EV Solutions Hub Motor Kit*
- *EVS Evo Electric Bike Conversion Kit*
- *Falcon EV Motor Conversion Kits with Lithium Batteries*
- *Zap Electric Vehicles, Light Electric Vehicles. and Electric Bicycle Conversion Kits*

Composite Wheels and Rims

High-end composite materials for wheels and rims have never before been so light, so strong, nor so readily available. The performance of your electric bicycle can be improved with such an upgrade, for these reasons:

- Resins or carbon-fiber composites achieve equal or greater strength with lesser weight.
- In many (but certainly not all) cases, these modern alternative materials can be cost-competitive with aluminum, and available in specialized design.

- One-piece wheels eliminate broken spokes and the need for traditional spoke-trueing, as well as improving the performance of the electric bicycle as a whole.
- One-piece wheels look amazing.

The following resources describe these alternative materials for wheels and rims. Many additional and worthy makers and resources have not been cited for purposes of brevity:

- Aerospoke Wheel Performance Technology
  http://www.aerospoke.com/
- "All-carbon Bicycle Rims Cost-competitive With Aluminum"
  http://www.compositesworld.com/hpc/issues/2006/November/1528
- Technically Advanced Geometry and independent review
  http://www.tagwheels.com/
  http://tyvek.com.mx/Sporting_Goods/en_US/assets/downloads/AP_bikewheel_F_K16831.pdf
- Zipp Wheels, with independent technology review of composite materials
  http://www.zipp.com/Technology/CompositeTechnologies/WhatAreComposites/tabid/98/Default.aspx

Consider the gains from the latest composite materials for wheels and rims. These materials can greatly increase performance with less weight, and they look amazing.

Integrated and Auxiliary Electronics

An e-bicycle can also provide power to or interoperate with electronic devices. One significant advantage of purchasing a turnkey electric bicycle is the potential for electronics integration in the design. The compatibility, interoperability, and perhaps even the protection of electronics can be integrated into frame design for consolidated purchase.

Other cyclists may prefer to keep portable devices elsewhere, rather than hard-mounted.

The following specific e-bicycles or devices illustrate how electronics are increasingly available to cyclists. This list is not comprehensive. Perhaps four more popular devices of relevance would be range calculator, battery status indicator, GPS, and PDA interface.

NOTE: If electronics and device interoperability are important to you, confirm such matters prior to a purchase of either a cycle or electronic device.

- *The Electric Motion Systems E+* includes a powerful LCD unit (removable) for micro-computerized power management and many additional functions such as cruise control.
- The rugged *Optibike OB1* integrates *GPS satellite navigation and a wireless PDA interface*.
- *There are several GPS units available* for bicycles, in general.
- *Electric Bike & Scooter Battery & Amp Hour Meter*

Integrated Safety

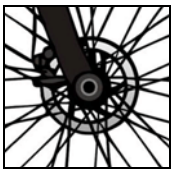
There are several components within a design that increase safety. This topic summarizes the following safety elements and benefits:

- *Waterproof Operation*
- *Appropriate Brakes*
- *Performance Suspension*
- *Lights*

Waterproof Operation

In the real world, most riders need the integrity and protection of a waterproof electric bicycle. Some manufacturers claim to have "water-resistant" bikes, but this is not the same as "waterproof." Waterproof integrity protects the rider from electric shock, and the bicycle from damage to the electrical system.

Appropriate Brakes



An electric bicycle travels two or three times faster than a conventional bicycle and weighs two or three times more. Disk brakes achieve reliable and robust stopping power when it is needful. Disk brakes last longer, require less maintenance, and work very well in wet conditions.

High-quality brand-name disk brakes will provide you years of service and the performance required over time.

Refer to the section *"Regenerative Braking for Electric Bicycles" on page 30* for further examination of regenerative braking for electric bicycles.

Performance Suspension

For the same reasons that disk brakes become a near necessity, appropriately robust front and rear suspension can be crucial to your safety and comfort. Impact with a pothole at 20 MPH or more without front and rear suspension could be traumatic to the rider and cycle.

With the electronics and electrical system within the bicycle itself, a robust and responsive suspension further protects the electronics from unnecessary bumps and prolongs the life of your investment, as well as increasing ride comfort and handling characteristics.

Lights

Integrated, bright, waterproof headlights and tail lights ensure that you can see and be seen, even under adverse conditions. Motorcycles in many states are required to have head and taillights on at all times. Integration into the bicycle's existing electrical system is an

efficient way to accomplish illumination without requiring additional batteries. In some cases, the consumption of electricity from the headlights can be monitored by an onboard computer. Furthermore, modern-day bulbs provide a great deal of brightness and durability that exceed that of previous headlight generations.

Safety is preeminent when assessing the technologies and design principles used for any electric bicycle on the market. These should include, at minimum, waterproof operation, robust brakes, stout yet flexible suspension, lights, and a frame that achieves maximum safety combined with maximum performance and usability. Make sure your electric bicycle will get you home even in heavy rain, then ask if it is guaranteed.

Regenerative Braking for Electric Bicycles

Many people who are familiar with hybrid-electric or purely electric automobiles are mindful of regenerative braking and the gains it delivers. Such braking changes the design of an electric motor so that it can partially recharge the battery when braking is applied. This is most often the case when braking to stop or going downhill. Such a function can increase the range of an electric vehicle.

An electric or hybrid automobile can support regenerative braking for several reasons, primarily because these are heavier vehicles, can carry heavier loads, and they cost more.

In contrast, regenerative braking *might* become a different proposition for electric bicycles. Some new models incorporate regenerating braking. These are some factors to consider:

- A motor must be more complex to integrate regenerative braking.
- Electronics must account for regenerative braking, making it more complex.
- Manufacturing is more intensive, and components cost more.
- The price to the consumer will be higher unless other factors can help with the resulting cost.

Regenerative braking has been implemented selectively on electric bicycles, perhaps starting in late 2007:

- *The Electric Motion Systems E+ electric bicycle is likely the leading example for bicycles that incorporate regenerative braking.*
- *BionX motor conversion kits include regenerative braking—unusual for conversion kits.*
- *The Matra MS1 electric bicycle incorporates regenerative braking.*
- *The new Panasonic electric bicycle also incorporates regenerative braking.*
- *Refer also to this article about the Panasonic Lithium Vivi -RX10S.*
- *The Euromoto BinBike is another example of a very recent model with regenerative braking.*

This would be one example of the alternate interpretation about regenerative brakes:

- *One review of Currie Technology's iZip electric bicycle* by the LA Times

The technology is here for electric bicycles. It has not been widely integrated into all designs, and it may never become the norm. At present, regenerative braking has not been widely evaluated by consumer feedback, but it can increase range.

Recharging Electric Bicycles With Alternative Energy

For those who are willing to invest in this approach, solar or wind technology can support the recharging of electric bicycles. This can be established in one of these general ways:

- The rider learns solar design well enough to build a custom solar recharging station, procuring the components and establishing the interoperability on their own, and likely in piecemeal fashion.
- The rider invests in a solar or wind energy kit, sometimes available as a recharging station specifically built for electric bicycles.

These would be a few products that support solar recharging of electric bicycles:

- One manufacturer has bundled two models of electric bicycle (unstated specifications) with a solar recharging station specifically for those cycles. See *Solar Electric Bikes*.
- One company manufactures a bicycle locker (available in multiple colors) with photo-voltaic cells on the roof. See the *21 Wheels Solar-Shell Recharging Station*.

NOTE: This specific topic will become one of the most active in the coming two years, given other developments.

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Summary Chart for State of the Art

To conclude this survey, the table below summarizes the components of current technology and design with related suggestions for a shopping strategy.

Table 4: Summary Chart of Electric Bicycle Technology and Design

Topic	Benefit Description and Advice
Battery Technology	*Insist upon a guarantee for the battery of any type, and ask your maker of choice about the progression of technology. and future support (replacement batteries and upgrades).* For additional information, refer to the section *"Battery Technology" on page 18*.
Calculating Range from Amperage and Voltage	Determine the range you need, then verify that the range and electrical characteristics of any candidate bicycle are accurate and true. *Advertised range may not match actual range.* Basic electrical formulas: • Watt hours (Wh) = Volts (V) x Amp hours (Ah) • 240Wh produces a rough range of 18 miles (29 kilometers).
Composite Wheels and Rims	Light weight for as many components as possible increases the power available for rider and for payload. However, quality, strength, and safety must not be sacrificed. *Consider the gains from the latest materials for wheels and hubs. Lightweight materials, when truly state of the art, can increase performance without compromising strength.*
Motors and Power Integration	Several types of motors and powertrain designs are available. Most models available fall well within established types and respective reputations. Higher-priced designs have benefits.
Gears and Efficiency	Neither the rider nor the motor cannot climb hills well, go very far, or accelerate at optimum rate without gears for both the motor and the rider. *Ascertain how an electric bicycle performs uphill, and how riding uphill and making frequent stops affects range.*
Battery and Motor Location	A low center of gravity can and will deliver superior handling, but it is not uncommon for some very popular bikes to have at least one battery (in a package of two) on a bike rack behind the seat. This will often be the smaller battery of the two.
Waterproof Operation	Waterproof integrity protects the rider from electric shock, and the electrical system from damage. *Insist on a waterproof electric bicycle if you will spend any time in rain or riding through water.*
Appropriate Brakes	Given the increased weight and speed of electric bicycles, conventional rim brakes likely do not supply sufficient stopping power, particularly when wet. *Disk brakes last longer, require less maintenance, and work very well in wet conditions.* Regenerative braking is partly available.
Performance Suspension	The greater speed and weight of electric bicycles create the need for suspension that exceeds that of normal bicycles. *A high-quality, name-brand front and rear suspension keeps the rider's body comfortable at higher speeds, and protects electronics.*
Lights	Waterproof headlights mean you can see and be seen, and integration into a high-wattage electric bicycle increases brightness and lifetime duration over previous generations of headlights. Integration eliminates the need for separate batteries or kinetic-based light generation.

Step 2: Strategizing a Purchase Decision

Introduction

This section discusses how electric bicycles are presented, itemizes features and cost factors that may or may not be obvious, and cites additional considerations as you prepare for a purchase. This step covers the following topics relating to shopping strategy:

Making Personal Choices With a New and Unique Vehicle

The previous section, *"Step 1: Surveying State of the Art" on page 10*, provides the foundation for understanding electric bicycles. That is a lot of material and a diversity of design.

This second step addresses specifications that you are likely to encounter when shopping. Shopping for an e-bicycle could be compared to shopping for a laptop computer —there are choices to make for battery technology, hard drive performance, operating system, feature sets, and peripherals. There is a learning curve.

- How to make sense of all this technology?
- How to decide when several different motors or drivetrains are available?
- How much range and power do you need?
- Is cost alone an indicator of quality?

This document emphasizes range, performance, and proven design.

Working Through Specifications

When the makers or dealers of electric bicycles list the specifications for their electric bicycles or conversion kits, they likely include the following. Many items listed here are presented in further detail in *"Step 1: Surveying State of the Art" on page 10.* Click the links below for additional details where desired.

NOTE: These specifications are increasingly available up front. Ask questions if they are not.

- ***Battery Technology***—The current state of affairs has batteries on the market ranging from (sealed) lead-acid, NiCD, NiMH, and Lithium-Ion. As described elsewhere in this document, Lithium-Ion-Cobalt is the most established version of the general Lithium-Ion technology, and may come with greater cost and benefits. Be sure to establish whether any battery under consideration is guaranteed.
  - ***Calculating Range from Amperage and Voltage***—Using these formulas, establish the true range, regardless of what the stated or advertised range is:

    Amp hours (Ah) x Voltage (V) = Watt hours (Wh)
    240 Wh = approximately 18 miles at 18 MPH

  - ***Time to recharge***—The greater the wattage, the greater is the time required to recharge a fully-depleted battery, generally speaking.
  - ***Lifetime Recharges and Disposal***—The total number of times that a fully depleted battery can be recharged until requiring replacement. This is an estimate. Proper and environmentally-responsible disposal should be taken into account prior to purchase.
  - Do you need a removable battery or batteries? Several models enable the removal of batteries so the e-bicycle can be left elsewhere while batteries are taken inside to recharge.
- ***Types of Electric Bicycles***—Establish the size and the type of the e-bicycle that you prefer. Refer also to *"Appendix C: Bicycle Type Questionnaire for Readers" on page 51*.
  - ***Adjustability***—Just how high or low does the seat on a candidate cycle rise? Tall riders should pay particular attention to this variable-it is not often reported as a standard practice, nor it is always discernible from pictures.
  - ***Wheel diameter***—The wheel diameter is sporadically reported by makers and dealers, and the buyer should take this into account if planning for riding offroad. A greater diameter can improve handling characteristics over rough terrain.
  - ***Suspension***—Does the suspension of the electric bicycle reduce shock to your motor, battery, and electronics?
  - ***Light-weight components***—How many components on the vehicle are made of the latest light-weight materials? One major consideration would be *Composite Wheels and Rims*.
  - ***Center of gravity***—As described earlier in this document, seek a low center of gravity to increase the quality of handling characteristics.
  - ***Folding***—Any folding bicycle will likely have this feature emphasized because it is very desirable for some or many buyers. However, folding capability may come with implied limitations, such as a smaller motor, decreased range and smaller overall size. Be aware of the possibility for such tradeoffs.

- ***Cost***—Additional factors relating to overall cost are described in the section *"Additional Cost Dynamics In a Purchase" on page 36* and *"Longer-Term and Sustaining Costs" on page 36*. You have strategy and options, and there may be the possibility of rebates at your disposal during the second half of 2008 or early 2009. This is highly dependent upon location.
- ***Motors and Power Integration***—There are five primary methods by which a DC-electric motor is mounted to an electric bicycle to apply power. Motor integration may or may not entail having the motor interoperate with a bicycle chain.
  - ***Motor type***—Aside from how the motor applies power to an e-bicycle, there are two basic types of motors to cover every possibility: (1) fairly conventional DC motors and (2) round, disk-shaped, wheel-mounted pancake motors.
  - ***Gearing***—How is the electric motor itself geared? Is it a one-speed-for-everything gearing in which the motor has to work significantly harder at high speeds, or does the motor have multiple gears, maximizing motor life?
- ***Range***—This is figure is typically reported as kilometers or miles per charge on a new battery, presumes level and paved ground, and likely does not presume pedal assistance from the rider. The range reported will likely presume that the maximum speed is no more than 20 MPH (29 KPH), unless otherwise stated. Refer to *"Calculating Range from Amperage and Voltage" on page 20*.
  - ***Range affected by hills and stop & go riding***—Ask how uphill riding and stop-and-go traffic impact the reported range for the electric bicycle under consideration.
- ***Top speed***—The top speed typically must comply with local legislative restrictions, typically cannot exceed 20 MPH (29 KPH) to qualify as an electric bicycle, and presumes level and paved ground with no pedal assistance.
- ***Weight***—The weight of the electric bicycle is largely determined by the motor and the battery. *However, you should not presume that overall weight indicates the true power of the vehicle.* The highest-performance electric bicycles include light-weight wheels, handlebars, and components that lessen weight. There are some compact electric bicycles, on the other hand, that weigh almost as much as a full-sized alternative.

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Additional Cost Dynamics In a Purchase

You can reduce or increase your purchase costs depending on a variety of circumstances.

- You may have to pay shipping costs when purchasing from out of state.
- However, purchasing from out of state may spare you sales tax.
- Seek out regional rebate programs that your local government might have as an incentive for purchasing an electric vehicle of any type. If they have nothing available, contact your city and county legislators with questions about their lack of incentives. They are way behind you at this point, perhaps by years.
- Light-weight performance components may increase cost and benefits.

Below are a few current programs that provide incentives for the buyers of electric bicycles. This is an investigation that remains highly dependent on a rider's location and ever-changing dynamics.

- Electric Vehicle Incentives in Austin, Texas, USA
  http://www.ci.austin.tx.us/cleancities/electricvehiclerebate.htm
  http://www.khou.com/news/state/stories/khou010308_rm_austinrebates.6fc75f4.html
- My-Go Program in Pasadena, California, USA
  http://www.worldchanging.com/archives/006635.html
- North Natomas Rebate Program in California, USA
  http://www.northnatomastma.org/bike_rebate.asp
- Sample Google search to start a personal investigation. Modify this search.
  http://www.google.com/search?client=safari&rls=en-us&q=electric+bicycle+rebates&ie=UTF-8&oe=UTF-8

Longer-Term and Sustaining Costs

An electric bicycle adds a few additional costs for a rider beyond normal cycling costs, to include the following:

- *Typical Electrical Costs*
- *Replacement Light Bulbs*
- *Replacement Battery and Lifetime Recharges*

Typical Electrical Costs

Electric bicycles consume very little electricity, for example in one hour of riding in Sport mode an average Optibike rider can cover about 30 miles with an average battery drain of 13 amps. The energy consumption in doing so is approximately 0.5 kWh - and costs merely 15 cents or so.

Replacement Light Bulbs

Latest-generation light bulbs may be able to deliver greater brightness with longer lifetime duration than bulbs included with some electric bicycles at time of purchase. We believe that an integrated light system, from the original manufacturer, is the best route to take, as you have lights that are confirmed to work with the bicycle from the time of purchase. Refer to "Integrated Safety" on page 29 for additional information.

Replacement Battery and Lifetime Recharges

Depending on your electric bicycle of choice, the replacement battery could total 25% or more of your original purchase price. These are some factors to take into account with regard to batteries and associated replacement costs:

- Lithium-Ion-Cobalt is currently the leading battery technology in this application. The benefits and advantages offered by this Li-ion-Cobalt technology deliver worthwhile performance that you are very likely to value, both immediately and over time.
- A manufacturer should guarantee the battery for a notably long period of time or mileage. One very notable example is Optibike, offering three years or 30,000 miles.

Getting Familiar with Range Requirements

Mapping Out Your Riding Routes

Have you mapped out the "territory" or distance that you travel most often? If you have not done so, you can do so now, using any of three quick resources, presented in alphabetical order.

Google Maps

1. Go directly to *Google Maps*.
2. Type in your complete starting address in the text field at the top left, and press **Enter**. A map with your location appears. You may wish to make this your default location. If so, click ***Make this my default location*** at the left.
3. Establish the distance to your most frequent destination.
   - Click **Get Directions**.
   - Move your current address to the **Start Address** field by clicking the small arrow.
   - Type in your new destination address and press **Enter**.
   - A route and distance appear. You can change distance to kilometers (km).

NOTE: The route and distance shown are oriented toward driving in a car. Account for the additional distance when taking safer bike routes instead.

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4. Repeat these steps as desired for any additional locations to which you will travel on a frequent or occasional basis. Map out as many locations as possible.
5. Keep these maps at your disposal, and move to the topic *"Brainstorming Range and Route Requirements" on page 39*.

Mapquest

1. Go directly to *Mapquest*.
2. Type in your complete starting address in the field at the left, and click **Search**. A map with your location appears. You can also input your first destination address when starting out.
3. Establish the distance to your most frequent destination.
   - Type in your new destination address and click **Go**.
   - A route and distance appear. You can change distance to kilometers (km).
4. Repeat these steps as desired for any additional locations to which you will travel on a frequent or occasional basis. Map out as many locations as possible.
5. Keep these maps at your disposal, and move to the topic *"Brainstorming Range and Route Requirements" on page 39*.

NOTE: Mapquest provides a much more flexible approach for mapping out multiple locations and destinations than does Google Maps. Mapquest can be used more easily to send such maps to a GPS system, or another portable device such as a cell phone or On Star navigation system.

Yahoo Maps

1. Go directly to *Yahoo Maps*.
2. Type in your starting address and the address of your most frequent destination (your first of several, likely). Click Go. Your starting and first destination locations appear.
3. Repeat these steps as desired for any additional locations to which you will travel on a frequent or occasional basis. Map out as many locations as possible.
4. Keep these maps at your disposal, and move to the topic *"Brainstorming Range and Route Requirements" on page 39*.

Brainstorming Range and Route Requirements

Once you have one or a few maps of your area available to you, and adjustable on a moment's notice, the following questions may help you to determine what range you really need, and what you might like to consider for enhanced range and power.

1. How much uphill riding (or in-the-snow riding) is implied by your maps and terrain? How much does this terrain increase the need for additional power?
2. How many of these destinations would you want at your disposal on a single trip, without having to recharge your battery?
3. What would you gain by doubling your range requirements?

   For example, how many additional destinations could you support, and how much new territory does this give you, if you were to purchase an electric bicycle with twice the range of what you think you need? Does this question increase the potential value of your investment as a long-term strategy?
4. How far could your range extend if you took mass transit systems into account?

Miscellaneous Questions to Ask Yourself

Aside from range, cost factors, and other matters already addressed, you might be able to save some time by asking a few additional questions, and evaluating their potential influence. Such questions would include the following:

1. Is an electric bicycle an appropriate choice for your lifestyle? Will weather hamper frequent use? Do you need greater protection? Would a different light electric vehicle or full-sized vehicle suit you better?
2. Does body weight influence the options available to you?

   Not to be insensitive, but a surprising number of electric bicycle have a limit of 165 lbs (75 kilograms) or *LESS*. This limitation influences appropriate options for countless millions of people. Even the most lean athlete might find that a lower wattage electric bicycle is very insufficient.
3. How tall are you?

   Your pant inseam may be a factor in appropriate cycle choice, particularly if you are 6'2" (188 cm) or taller. Several e-bicycles support taller riders, but many might not.
4. Will security be a major factor a majority of the time, or even some of the time?

   A heavy-duty cable lock can accomplish much, but an electric bicycle will not afford the security that a locking car might. To discourage curious hands, and perhaps to offer some outdoor protection, perhaps a market can develop for heavy and independently locking canvas covers—perhaps not.

Step 3: Seeking a Worthy Manufacturer

Introduction

This section emphasizes the importance of the bicycle maker to your quest for a perfect purchase, and contains the following topics:

At the risk of repetition, the primary points we emphasize in this document are as follows:

- Question the math reported by any manufacturer as a standard practice. This is cited in the section *"Calculating Range from Amperage and Voltage" on page 20*.
- Get as much wattage and amperage as you can afford. This suggestion is repeated widely and often by multiple parties in industry.
- One can no longer presume that a very large-sized company can deliver contemporary benefits or long-term staying power. Look at momentum and enthusiasm of customers.

Questions to Ask About Manufacturers

An electric bicycle should be considered a serious long-term purchase. The maker has as much relevance to your interests as does the bicycle. Guidelines and factors in choosing a maker would include the following:

- Has the company embraced state-of-the-art components? The first two steps in this document describe this element in greater detail.
- Does the company have a track record of excellence and accessibility, combined with a forward-looking momentum?
- Does the company have a loyal and enthusiastic following?
- What do independent third parties in industry generally recommend or advise?

Notable Electric Bicycle Makers Supporting 250 Watts or More

Table 5 below itemizes manufacturers and what is known of power train equipment in their designs. We currently emphasize *turnkey* electric bicycle makers that offer, at minimum, 250 watts of power in at least one of their electric bicycle models.

For motor conversion kits, refer to the *"Third Party Electric Bicycle Manufacturer Lists"* topic for separate and additional resources.

Several parties often repeat that a customer should pursue as much electric power as possible. This philosophy supports a longer-term perspective for ownership.

Existing owners of prior technology often bemoan a lack of range and uphill performance for those prior-generation electric bicycles. Be selective in the bicycle models and makers you consider. You can be selective and sustain high expectations at this time.

Third Party Electric Bicycle Manufacturer Lists

Most of these third party manufacturer lists describe the manufacturers of turnkey electric bicycles, but a few of these resources cite the manufacturers of conversion kits.

NOTE: Any additional lists that have not been updated since 2006 are no longer current. Such lists are likely to cite companies that are no longer in business, dated specifications, or discontinued models/products. The past two years have been dynamic.

- Bicycle-Power.com—One superior listing of conversion kit manufacturers, worldwide
  http://www.bicycle-power.com/diykits.html
- Econogics Electric Bicycle Manufacturer List
  http://www.econogics.com/ev/evbikes.htm#Bicycles
- Electric-Bikes.com's Electric Bicycle Manufacturer List
  http://www.electric-bikes.com/bikes/index.html
- Energy.SourceGuide.com's list of electric bicycle businesses, by country
  http://energy.sourceguides.com/businesses/byP/ev/eBike/byGeo/byC/byC.shtml
- ExtraEnergy.org Electric Bicycle Manufacturer List
  http://www.extraenergy.org/main.php?language=en&category=products&subcateg=&id=1639
  http://www.extraenergy.org/main.php?language=en&category=products&subcateg=37

Summary Chart of Electric Bicycle Manufacturers and Models

This is a representative listing of turnkey e-bicycles starting at 250 Watts, *not a comprehensive resource list*. Conversion kits are cited elsewhere.

Most turnkey e-bicycles known to have been discontinued as of 2008 are not included. A review of *"Appendix B: Additional Resources" on page 48* will certainly reveal additional models on the market.

Table 5: Electric Bicycle Manufacturer and Model Summary

Manufacturer/Brand	Model	Frame Type(s)	Advertised Range	Power Control	Battery Type(s)	Motor or Drivetrain
50cycles Electric Bikes Loughborough, UK	Multiple models	Scooter Sport Urban Cruiser	Varies Up to 50 mi (80 ki)	Manual or Pedelec	Li-ion MN	250W (varies)
Avon Cycles New Delhi, India	Multiple models	Scooter Compact	Varies	Varies	Varies	Varies
Belize Bicycle Lasalle, Quebec, Canada	E-RIDER MTB	Mountain	Over 30 km (18.6 mi)	Manual + Pedelec	36V-8Ah NiMH	350 W Hub motor
BikeTec Kirchberg, Switzerland	Flyer T8 Premium	Touring	36 km (22 mi)	Manual	Li-Ion	Panasonic Drive 8-speed hub gear
Currie Technologies, Inc. Chatsworth, CA, USA	iZip Series	Hybrids Urban Mountain Cruiser Scooter Compact	Varies by model	Electro-Drive™	Sealed lead-acid, NiMH and Li-Ion Choices	Up to 450W or greater Multi-speed gearing for motor and rider
Daymak Canada, China, Italy	Multiple models	Mountain Urban Compact	Varies by model	Not listed	To 36V Lead-acid, NiMH, NiCd or Li-Ion,	250W but varies by model Multiple gears
Eco-Brand Exim China	Multiple models Samurai model cited at right	Mountain Urban Hybrid Compact Scooter	Not available	Pedelec or optional throttle	3 x 12 Volt 8Ah Sealed Lead Acid, with NiMH or Li-Ion optional	250W
EcoBike *Medford, OR, USA* (Headquarters) Global distribution	Vatavio Elegance Adventure	Compact Hybrid/ Cruiser Sport	18-25 mi (29-56 km)	Trad'l PAS Throttle only	36V, 8A Li-MnO	290W - 360W (700W peak) Hub motor

Table 5: Electric Bicycle Manufacturer and Model Summary (Continued)

Manufacturer/Brand	Model	Frame Type(s)	Advertised Range	Power Control	Battery Type(s)	Motor or Drivetrain
eGo Vehicles International	eGo Cycle SE	Compact	40 km (25 mi)	Manual throttle	Lead-acid 24V, 34Ah	24V brushed Belt-drive
Elebike International Taipei, Taiwan	RU 202 Giga-105 Giga-07	Compact Hybrid	10 km, 20 km, or 25+ km (6-15+ mi)	Manual + pedelec	7Ah, 24V 12Ah, 24V 36V x 7Ah	250W
ElecTrec Electric Bikes New York City, NY, USA	ElecTrec & Police	Sport/Urban Hybrids	32 km 20 mi	Manual throttle	24V, 14A	600 W 8-speed
Electric Motion Systems, Inc. (EMS) Dulles, VA, USA	E+ Series	Mountain Cruiser	20-40+ (32-64+)	Very high-tech Manual or Pedelec 19 modes	36V, 9 Ah NiMH Hub-mounted	750W-1000W Disk motor
ElectrikMotion, USA	*Rayos* (replaces ElecTrek & Lash Out in 2008)	Urban-mountain hybrid	32 km 20 mi (with some pedaling)	Manual	24V, 14Ah	600W or 750W Frame-mounted motor w/ chain 8-speed
Electrobike, LLC San Francisco, CA, USA	Electrobike Pi	Patented semi-cruiser(?)	30 miles at 20 MPH 60 miles optional (48-96 km)	Manual throttle	36 V, 50 Amp NiMH	750 W In-line chain drive Semi-auto trans
Euromoto/BinBike Bornem, Belgium	BinBike Europe	Touring	25-40 km 15-25 mi	Pedelec	24V, 10Ah NiMH	250W 6-speed
EV Global Motors Google search for EV Global Motors	EV Global Motors, based out of Taiwan, is difficult to categorize. They were under the leadership of Lee Iacocca starting in the mid to late 1990s. Their premiere product, the E-bike™, was much heralded when launched, but has suffered numerous setbacks during its presence on the global market. The corporate website is no longer available at this time, though commonly cited: http://directory.officer.com/buyersguide/VEHICLES/Bicycles_and_accessories/Ev_Global_Motors_Co_1899.html					

Table 5: Electric Bicycle Manufacturer and Model Summary (Continued)

Manufacturer/Brand	Model	Frame Type(s)	Advertised Range	Power Control	Battery Type(s)	Motor or Drivetrain
Ezee Bikes Extensive international presence	7 models available	Cruiser Hybrids	40-80 km, depending on mode (25-50 mi)	Manual throttle or pedelec	37V, 10Ah Li-Ion (LiMnO)	200W (Australia, NZ, Singapore), 250W (EU) , 350W (USA) Frame-mounted motor
Giant Electric Bikes Extensive international presence *One sample review here.*	*Twist Freedom DX* *Suede E*	Urban Hybrids	70 miles reported (112 km)	Pedelec only	Two 26V	250W Hub motor (non-disk) 7-speeds to rider
IKOO, LLC	*Electric Scooter*	Scooter	15-18 m i (25-30 km)	Manual Throttle	24V 12Ah SLA	600W Rear belt drive
Koga Miyata Glasgow, Scotland	*Tesla Series*	Urban Hybrid	Not available	Pedelec only	NiMH	Rear hub motor 21 gears
Ohm Cycles, Ltd. Vancouver, BC, CA	Ohm Series (4 models)	Urban Sport	*See BionX specifications*	Manual Supports generative pedaling	Li-ion 26V-38V 9AH-12Ah	Up to 350W (700 peak) BionX
Optibike, LLC Boulder, Colorado, USA	400 600 800 OB1	Monocoque Sport	25-60 miles, depending on model and mode (40-96 km)	Manual	36 V 13Ah, 20Ah, or 25Ah Li-Ion-Cobalt or NiMH	400W-850W Internal frame motor with MBB™ 9-speed drivetrain
Prima Power Bikes Turata, Italy with wide international presence	Multiple models available, Light model cited at right	Urban Hybrid Compact	25-35 km, depending on mode (15-22 mi)	Pedelec (manual mode control)	36V, 5 Ah	250 W Front hub motor

Table 5: Electric Bicycle Manufacturer and Model Summary (Continued)

Manufacturer/Brand	Model	Frame Type(s)	Advertised Range	Power Control	Battery Type(s)	Motor or Drivetrain
Tres Terra	Recently acquired by Ultra Motor USA, Inc. Refer to Ultra Motor USA, Inc. information cited immediately below.					
Ultra Motor, Inc. Newbury Park, CA, USA Add'l international presence	Three models offered	Hybrid Perfor-mance Compacts	20 miles Upgrades to 40 miles optional (32-64 km)	Manual	36 V, 10 Ah Li-Ion	400W or 500W Hub motor 7 gears for rider
Urban Mover Bikes Extensive international presence	UM24 UM36 UM44 UM44L UM55	Compact Sport Hybrids	Varies. UM44L = 35-45 km (22-28 mi)	Manual & Pedelec	UM44L: Li-Ion with 26 V, 12Ah Li-Ion Polymer option	UK & AUS: 200W Europe & USA: 250W 6-speed
Veloteq, Inc. Houston, TX, USA	Multiple models	E-Scooters Urban Hybrids Compact	Varies	Manual or Pedelec	Sealed lead acid	500W Gear-reduced motors
Wavecrest Laboratories, Inc. Dulles, VA, USA	Until discontinued, the Wavecrest **Tidal Force** series had wide visibility in the market, particularly in the USA and Europe. The Tidal Force series served as a benchmark in several ways, given 750W total power. Consider this dated industry announcement as one example of its visibility: http://www.topratedadventures.com/MFG/tidalforce.htm Click here for presentation and pictures of Tidal Force models: http://www.electrikmotion.com/Tidal%20Force%20Electric%20Bike.htm					
X-Treme Scooters Newton, Iowa, USA	Many light electric vehicles	ATV Bicycles Mopeds Scooters Motorcycles	Varies	Varies	Varies	Varies

Appendix A: Glossary

NOTE: This document uses the following terms according to the respective definitions provided below. Your experience and usage may vary.

Bicycle Frame

This is the central component of any bicycle. A frame can consist of a tubular skeleton, as with conventional bicycles, or a scooter-like U-shaped body and additional panels. A frame can be monocoque (shell) design, or partial monocoque, in which electrical components are hidden within the frame itself. The wheels and handlebars attach to the frame. The frame is most often (but not always) the location at which batteries and motors are installed to provide electric power drive. There are multiple and diverse bicycle frame types that support electric power assistance.

Refer to the section *"Types of Electric Bicycles" on page 11* for more information about how electric bicycle frame types can differ.

E-bike

The term E-bike™ is an international trademark by EV Global Motors, Inc., and is the name for their premiere product line of electric bicycles, established under the leadership of Lee Iacocca. However, perhaps as "Coke," a registered trademark of Coca-Cola Inc., can refer to about any carbonated soft drink, the term "e-bike" has become a general term for any type of electric bicycle. This document resists such usage.

Electric Bicycle

This is a bicycle in which electric power, in the form of an electric motor and one or more batteries, aids the rider with greater acceleration and sustained speeds over extended range. Electric bicycles can be purchased as production turnkey models, or conventional bicycles can be converted to electric power assistance with aftermarket motor and battery conversion kits, making them electric bicycles.

Power assistance is controlled with a hand throttle, or by activating electric drive through pedaling, or both. The European term *pedelec* refers to pedal-activated power assistance. Otherwise, electric bicycles are also known as e-bicycles, e-bikes, power-assisted (bi)cycles, and electric bikes. Electric bicycles are typically restricted by law not to exceed 20 miles per hour (rounded to 30 kilometers per hour in metric jurisdictions), across level and paved ground without the rider pedaling. Increased speed is possible and legal if and when the cyclist pedals in combination with electric power assistance.

Electric Scooter

An electrically-powered two-wheel cycle that typically has a U-shaped frame and body, very much like the Italian Vespa, a floor board or foot rest, and may or may not have pedals. Many e-scooter models have pedals as with a Moped, and many recent electrical models do not have pedals. Electric scooters often have wattage similar or equivalent to electric bicycles. Electric scooters may increasingly require an operator license, but this is perhaps the largest unanswered question at the time of publication.

Hybrid

This is a widely-used term, perhaps even useless, that can refer to multiple things:

- *Hybrid* can refer to the combination of human power with electric power assistance on a bicycle. *This concept is commonly known as an "electric bicycle."*
- *Hybrid* can refer to a combination of offroad and urban design, to produce sportier bicycles for urban use, for example.
- *Hybrid* could refer to a combination of manual (throttle) and foot (pedelec) controls for activating and controlling electric power assistance. In other words, *hybrid* can mean a combination of electric drive and electric power assistance.
- *Hybrid* can refer to an automobile or other alternative energy vehicle that combines electric drive with a fossil-fuel combustion engine, for example.

Motor Conversion Kit

Refers to an aftermarket kit, comprised of an electric motor and one or more batteries, that mounts to a conventional bicycle, converting it to electric power. These are restricted by law to the same legal definition as electric bicycles. They can be relatively straightforward for installation, or more complex, depending on the skills of the home-installer.

Pedelec

The European term *pedelec* refers almost exclusively to electric bicycles in which power assistance is activated by pedaling, as opposed to manual throttle control.

Power Assistance

Power assistance is when electric power aids or assists pedaling from the rider, rather than replacing it. This is often called *pedelec* control, and this contrasts with electric power or e-bike mode, in which the rider has the option of using all electric drive without pedaling.

Turnkey

This term refers to an electric bicycle that is manufactured as such. This contrasts with motor conversion kits that are installed by the consumer onto a conventional bicycle after purchase of both. Turnkey e-bicycles are more expensive than conversion kits installed on conventional bicycles, but turnkey cycles benefit from many things, to include wholistic design and manufacture, with warranty. Additional benefits are common.

Appendix B: Additional Resources

This section itemizes a very wide range of resources that track, report, and comment about electric bicycles and light electric vehicles (LEVs) in industry and in society.

Electric Bicycle Resources

The following resources have a specific focus on electric bicycles. This list is not comprehensive, and could double in size every two months to keep up with ongoing activity and market dynamics.

Table 6: Online Electric Bicycle Resources

Resource	Category	Live Link/URL
Electric Bikes Worldwide Reports	Global industry research, $300 US	http://www.ebwr.com/
Electric Bicycles: A Guide to Design and Use by William C. Morchin and Henry Oman (This book cost $29 US a few months ago.)	Retail Book, $45 US November 2005, IEEE Press	http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471674192,miniSiteCd-IEEE2.html
ExtraEnergy.org	Leadership in free industry evaluation	http://www.extraenergy.org/main.php?language=en
ArticlePros' *Why to Use an Electric Bicycle?*	Article(s)	http://www.ArticlePros.com/automotive/motorcycles/article-86984.html
Earth Times' *Cycling Gets a Power Boost from Pedelec, E-Bike Trend*	Article(s)	http://www.earthtimes.org/articles/show/197945,cycling-gets-a-power-boost-from-pedelec-e-bike-trend.html
Electric Bikes and Scooters	Article(s)	http://electricbikesnscooters.com/
Ezine Articles' *How to Fit Electric Bicycles Into Your Life*	Article(s)	http://ezinearticles.com/?How-to-Fit-Electric-Bikes-into-Your-Lifestyle&id=553932
Green Living Online's *Electric bicycles for commuting*	Article(s)	http://www.greenlivingonline.com/GettingAround/electric-bicycle-for-commuting/
New York Times' *A Two-Wheeled Option (With Battery) For Commuters*	Article(s)	http://www.nytimes.com/2007/05/06/business/yourmoney/06bikes.html?_r=1&scp=3&sq=electric+bicycle&st=nyt&oref=slogin
Can Seattle's...electric bicycles move as many people as Freeway 167 full of 60 MPH cars?	Blogging	http://abramsonrl.blogspot.com/2008/05/how-seattles-interurban-bicycle-trail.html
CycloCulture—Journal for Real World Cyclists	Blogging	http://cycloculture.blogspot.com/2008/06/electric-bicycles-china-style.html

Table 6: Online Electric Bicycle Resources

Resource	Category	Live Link/URL
Floating Down Denial: The EV Global Motors eBike Rides Again!	Blogging	http://downdenial.blogspot.com/2008/04/ev-global-motors-ebike-rides-again.html
Hurdles for a New Transportation Technology (covering conversion kits and manufacturing)	Blogging	http://gristmill.grist.org/story/2008/5/29/14554/0835
Wikipedia.org's English article on **electric bicycles**	Blogging	http://en.wikipedia.org/wiki/Electric_bicycle_laws
Armybikes.com's *Why Go Electric?*	Commentary	http://www.armybikes.com/electricbikes.htm
Electric-Bikes.com's manifesto for personal electric vehicles	Commentary	http://electric-bikes.com/manifesto.html
Persistent Illusion's *How to Buck Conventional Wisdom*—June 11, 2008	Commentary (sharply sarcastic)	http://persistentillusion.wordpress.com/2008/06/11/how-to-buck-conventional-wisdo/
Electric Bicycle Forum—EBike Information Hub	Forum	http://www.ebikehub.com/forum/
Google Groups forum for Tidal Force cyclists and electric bicycle fans	Forum	http://groups.google.com/group/Tidal-force?hl=en&lnk=sg
V is for Voltage Online Forums, blogging the users of multiple models	Forum	http://visforvoltage.org/forums/electric-rides/bicycles-and-pedelecs
EV World's *Electric Scooter/Cycle Guide*	Guidebook	http://www.evworld.com/guide_ecycle.cfm
Mother Earth News' *Four Rules for Choosing an Electric Bike or Scooter*	Guidebook	http://www.motherearthnews.com/Green-Transportation/2007-02-01/Four-Rules-for-Choosing-an-Electric-Bike-or-Scooter.aspx
My-Moto.com's *How to purchase the best electric bicycles online*	Guidebook	http://www.my-moto.info/
Optibike's *Five Things You Must Know Before Buying An Electric Bike*	Guidebook	http://www.optibike.com
eBikes.ca—Vancouver, British Columbia, CA	Industry Evaluation	http://www.ebikes.ca/index.shtml
Electric Bike Network	Industry Evaluation	http://www.myebike.com/
Electric Vehicle Council of Ottawa (EVCO), CA	Industry Evaluation	http://www.evco.ca/ebike.html
Bicycle-Power.com's inventory of suppliers and technology resources (partially outdated)	Industry Reference	http://www.bicycle-power.com/electric.html
Bicycle Retailer and Industry News	Industry Reference	http://www.bicycleretailer.com/
Articlesbase.com's *Electric Bicycles*, 5/23/08	Product Reviews	http://www.articlesbase.com/automotive-articles/electric-bicycles-368345.html
AtoB.org.uk—Articles and reviews of several light electric vehicles, with buyer guides	Product Reviews	http://www.atob.org.uk/
Seven Generational Ruminations' *Electric Bicycle Booklist*	Retail Books	http://www.7gen.com/website-categories/electric-bicycles?page=1

General News and Research Sources for Light Electric Vehicles

The following websites constantly follow the general industry of light electric vehicles:

Table 7: General LEV Information Sources

Resource	Live Link/URL
Alternative Energy Blog	http://alt-e.blogspot.com/2006/09/plug-in-hybrid-campaign.html
Electric Drive Transportation Association	http://www.electricdrive.org/
Electric Vehicle World	http://www.evworld.com/
Endless-sphere.com's Consortium on Electric Vehicles	http://endless-sphere.com/forums/index.php?c=2
Environmental News Network	http://www.enn.com/
ExtraEnergy.org An active information center for light electric vehicles, with much investigation into electric bicycles	http://www.extraenergy.org/main.php
Free Energy News	http://freeenergynews.com/Directory/EV/
Green Car Congress	http://www.greencarcongress.com/
Grist—Environmental News and Technology	http://grist.org/
Transportation Research Board	http://www.trb.org/

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Appendix C: Bicycle Type Questionnaire for Readers

This questionnaire and analysis may help you narrow down your preferred bicycle type. If you already know that you need a compact bicycle, and perhaps one that folds, then your preferred bicycle type is already known. Answering these questions could help you determine secondary attributes that you may like.

Five Questions

This questionnaire focuses on the ergonomics and utility of three full-sized bicycle types. Answer each question, then follow the analysis in the next topic. This questionnaire is unique to this document, and does not imply industry-standard profiling.

NOTE: This questionnaire emphasizes ergonomics and rider application.

1. How do you prefer to sit for the majority of your intended (power-assisted) riding?
   - A Leaning forward, perhaps in more competitive or physically-demanding fashion.
   - B Sitting upright or leaning a little forward, particularly given the power assistance.
   - C Sitting fully upright or laid-back even further.
2. What type of bicycle seat is the most preferable to you?
   - A I need a performance seat. I'm (perhaps) willing to sacrifice some comfort to aid in aggressive or competitive riding.
   - B I want more comfort than a typical sport seat, but with ergonomic comfort when pedaling on a frequent basis.
   - C I want the most comfortable seat possible. Not having to pedal much is one reason I'm considering an electric bicycle in the first place.
3. How important to you is the ability to carry cargo?
   - A I'm willing to give up a rack and cargo capacity, or prefer something smaller and quickly removable.
   - B I want the possibility of good cargo capacity, whether for regular grocery trips, holding a brief case, or for regular extended day trips.
   - C My bike will be for getting around easily. Cargo and a rack is not much of a factor, but I like options.

4. How does bicycle weight factor into your thoughts?
   - A I appreciate the option of lighter-weight components to increase performance, handling, and range.
   - B Weight is a factor for me because I anticipate carrying or lifting the bike on a fairly regular basis (such as going up stairs).
   - C I don't anticipate having to think about weight (no regular lifting or competitive riding anticipated).
5. What kind of terrain will dominate your riding?
   - A Rough and offroad terrain, or very demanding urban riding or touring.
   - B Urban and paved riding, but I don't want to sacrifice general versatility.
   - C Paved and easy riding over flat surfaces or easy hills.

Tallying Your Results and Defining Your Preference

1. Tally up your five responses by letter, such as B-A-B-C-C, for example.
   - For every "A" response, assign a value of 1.
   - For every "B" response, assign a value of 3.
   - For every "C" response, assign a value of 5.
2. Add up your personal score. If you answered "C" for each of the five questions above, you would have a total of 25, for example.

Your total score is between 5 and 25. One interpretation of your number is as follows:

A Score of 5 to 9

If you scored between 5 and 9 (roughly), you are likely to be a rider who seeks performance or physically involved riding over dynamic terrain. A mountain bike frame with dynamic suspension could be a high priority for you. Other obvious features that are likely to appeal to you would be straight or nearly straight handlebars, a compelling need for uphill performance, but perhaps with the option of adding a rack and some cargo capacity for touring trips or commuting.

A Score of 11 to 19

If you scored between 11 and 19, you likely have the most options available to you. This range largely covers most urban, much touring, and utility bicycles. If you scored just below 15, you likely prefer sportier features or options. If you scored just above 15, you likely prefer slightly more casual features, options, or riding position.

Any Score Above 15

The higher your score is above 15, the more likely you are to prefer a "cruiser" type bicycle. You are likely to seek a pure cruiser if your total was from 21 to 25. Casual riding, easy-up or laid-back posture, and easiest on/off usability are likely to be your strongest preferences.

Your Taste May Vary

Simply put, one way to determine your primary chassis or frame preference is by taking posture, handlebar shape, and seat preference into account. Much or most of the rest move from these. Certainly this overview seems like an oversimplification. The market supports a wide diversity of riders and designs, and visual generalizations can be helpful.

Electric drive and pedal assistance deliver performance for any type of bicycle frame. Refer to the section *"Types of Electric Bicycles" on page 11* for additional information about bicycle frames.

NOTE: This is a general categorization, and there are exceptions to nearly every norm at the present time. You can find a compact urban electric bicycle with dynamic suspension and shock absorption, for example.

Appendix D: Light Electric Vehicles and the Environment

Fossil-Fuel Dependence and Electricity Generation

Anytime a bicycle replaces the use of an automobile or a fossil-fuel-dependent engine, greenhouse gas emissions are reduced. That is one fundamental contention of this document. However, this premise is by no means established without open disagreement or criticism. The bone of contention is how electricity gets generated.

Regrettably, the generation of electricity in the United States remains largely dependent on fossil fuels, as it does in many other countries. One implication is that electric vehicles are indirect contributors to fossil-fuel consumption when operated within such electric grids.

We contend that the efficiency of modern electric vehicles offsets the liability of operating in a fossil-fuel-dependent electric grid. Electric vehicles often remain more efficient than do combustion engines, and of themselves, electric vehicles do not produce greenhouse gas emissions. The question becomes how to consume fossil fuels in the most efficient manner possible, and electric bicycles have compelling points in their favor.

To provide general perspective, the primary sources of electricity generation in the USA are as listed below.

Table 8: USA Electricity Net Generation (Billion Kilowatt Hours)[a]

Generation Type	2004	2010 (Projected in 2004)
Total Fossil Energy	2809	3108
Total Renewable Energy	351	476
Nuclear	789	809
Other	6	12

a.Source: *Power Technologies Energy Data Book*
http://www.nrel.gov/analysis/power_databook/docs/pdf/db_chapter07_1.pdf

Greenhouse gas emissions from combustion engines nearly match such emissions from energy generation or industry:

- The USA EPA's "US Greenhouse Gas Inventory Report"
  http://www.epa.gov/climatechange/emissions/usinventoryreport.html
- Pew Report's Innovative Policy Solutions to Global Climate Change, "Figure 1: Sources of Greenhouse Gas"
  http://www.pewclimate.org/docUploads/policy_inbrief_ghg.pdf
- "America's Biggest Belchers" (of greenhouse gases)
  http://scitech.blogs.cnn.com/2008/04/09/americas-biggest-belchers/

Afterword

Congratulations. You have read, reviewed, or used as reference one the best summaries of electric bicycles that we believe to be available in this industry, and it was free. Hopefully, the result is that you have the foundation for joyful and informed investigation, or perhaps even some action. *What now?* If you have not already done so, please consider one or more of the following actions:

- Commence your search for an electric bicycle to suit your needs.
- Select a wisely-chosen electric bicycle, and use it multiple times per week.
- Consider emailing this document's location to family or friends for their consideration.
- Investigate the incentives and rebates, or lack thereof, in your state or community for owners of electric vehicles.

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