

“Should My E-Bike Have Regenerative Braking?”

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This question is one of those curiously persistent phantoms of the E-bike world. It stems from a simple engineering fact about electric motors - if you put electricity into a motor, it spins. If you spin the motor (with your hand, for example), electricity comes out. Free energy? Hallelujah! All you need to do now is hook up a battery - conveniently, E-bikes happen to come with one already attached - and you're well on your way to being totally off the grid, or at least occasionally disconnected. This makes for some great marketing buzz - which is why so many E-bike manufacturers are so keen to let you know all about it.

Unfortunately, the reality is not as grand as the fantasy; the laws of physics, once again, intervene.

To start with, simply building a bike capable of doing regenerative braking requires you to use a direct-drive motor - all of which are larger and heavier than geared and mid-drive motors, and which (due to their inherent design) make pedaling into a chore through a phenomenon called “cogging torque”; imagine if your bike felt as though it had a flat tire every time you started pedaling. Not a great feeling, and one of the main features that nearly every E-bike rider wants is an E-bike that can be pedaled as easily as a normal bike. With a DD motor, you've thrown this feature out the window on the first go. Some designs attempt to minimize cogging, but all suffer to some degree. At higher speeds, this effect dissipates and becomes unnoticeable, but at the moment when most people will be pedaling - to start the bike in motion from a complete stop - is when the effect is at its strongest. So, not great.

An interesting fact about DD motors is that they all give you some sort of “regeneration”, whether you want it or not, simply due to the way they're put together. This is in fact how this whole thing got started - people figured that, if you're going to get the power back anyway, why not use it? Thus, “regenerative braking” was born! Originally a sort of “bug”, and now a “feature”. Cool - a little disingenuous, but still cool. This is partly why this subject is so confusing - regenerative braking is not a feature you add, it is a phenomenon you manage.

Geared and mid-drive motors, incidentally, cannot easily be made to regenerate. This is due to the fact that they contain a freewheel device which disconnects the rear wheel

from the motor, preventing that wheel from driving the motor (and thus regenerating). It is in fact possible to design a geared or mid-drive system that allows regeneration, but the list of engineering tricks required for this is lengthy, and has generally not been attempted by most serious E-bike makers.

On top of all these challenges, the amount of power you get back with an E-bike is extremely small. Under the best route conditions, with the finest designs and an attentive rider who is specifically aiming to maximize their return, you can manage something like 5-10% battery capacity return. The average rider is likely to experience something like 2%. Why? Well, E-bikes don't weigh very much, they don't go very far, and the only time the "regenerating" is going on is when you are coasting down a hill or some such, so the actual force available for the motor to turn back into electricity is already pretty small. Add to this a number of fiddly engineering details - like the fact that you can't put electricity into a battery as fast as you can take it out (which means some % of the power you're "regenerating" simply dissipates as heat because it cannot physically go into the battery quickly enough), or that while braking at high speeds, 75% of the braking force is going into the front wheel, rather than the back (where your motor is) - and you can begin to see how this all adds up (or rather, how it doesn't).

So, just from the start, you're already pushing a rock up a hill here. You have to use the biggest and clunkiest motors, and you're not getting all that much back for your effort. There have been some clever ideas over the years in the way of maximizing your return, and like all engineering challenges, you have to spend some combination of money, weight, and reliability to make it happen. On top of all that, with an E-bike, the forces are so low and the returns so small that most of what you gain from all this effort in maximizing your return is going to be eaten up by the weight and torque resistance of the components you so cleverly designed to get all of this energy out to begin with. It is in fact possible to design an E-bike with regenerative braking that *loses* range because of this.

Now, this isn't to say that regenerative braking is all marketing hocus-pocus or some insoluble mystery. It's a clearly-understood phenomenon that works great on heavy vehicles like electric cars. But an E-bike is its own beast, with its own delicate balance of capability and cost, and at the moment there are no really good, cost-effective way of building a bike with this ability in mind. At best, it is an additional capability that you happen to have anyway because you chose a direct-drive motor. At worst, it's a disingenuous "feature" that the vast majority of riders will never benefit from.

For the engineer, the most straightforward way of adding range to your bike is to simply equip it with a higher-capacity battery (and a geared or mid-drive motor), rather than trying to squeeze out every joule you can from your rear wheel. For the marketing people, the best philosophy is probably this: If you don't have it, don't worry about it. If you do have it, be honest about its capability and let the consumer decide for themselves whether it fits within their needs. A grandmother in Florida doesn't need it (or even know what it is). A bike messenger in NYC might like to have it. An E-bike nerd who commutes through LA will treat it as though it's the second coming. All three of these people are right.

Further reading:

<http://www.soltechdesigns.com/regen/>

<http://www.ecospeed.com/regenbraking.pdf>

<http://www.nycewheels.com/self-charging-electric-bike.html>

<http://www.evelo.com/blog/why-dont-more-bikes-use-regenerative-braking/>

http://www.expandingknowledge.com/Jerome/Bike/Gear/Electric/Regeneration/Effectiveness/2008_08_13_Wondering/Main.htm