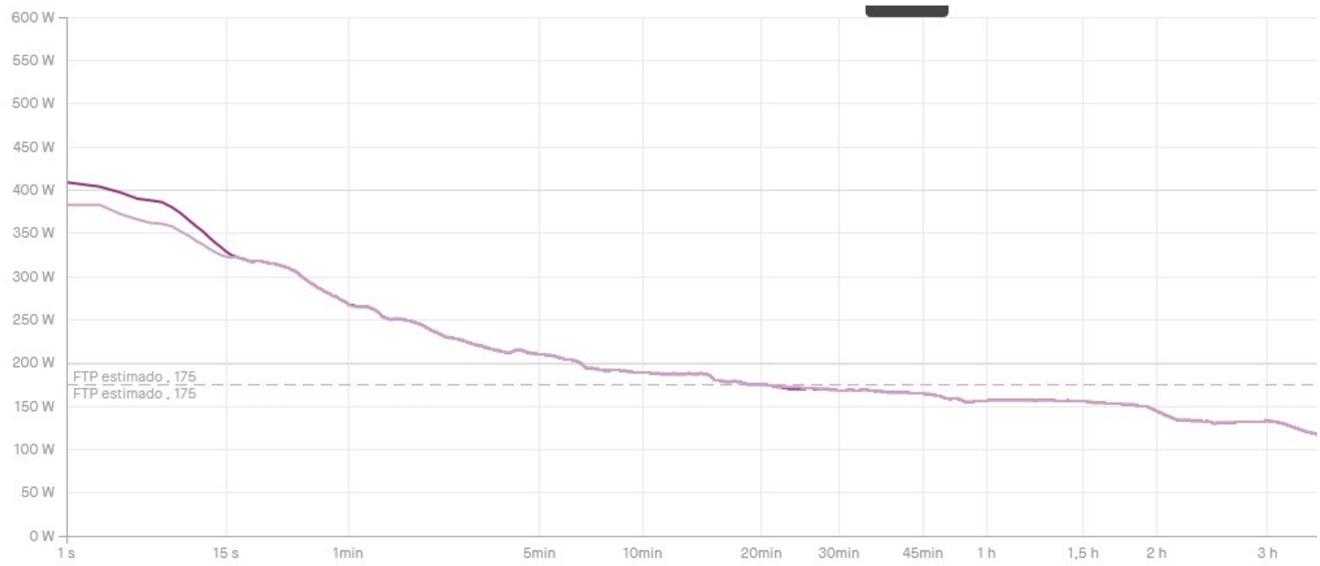
A proposed methodology for the optimal determination of assistance levels in an Ebike

Disclaimer: This is a draft document in which I allow myself to suggest a methodology based on my experience, road tests and studies carried out in the world of cycling by scientific experts. It is a first order of ideas that will be improved with the feedback of other users. It must be seen as a starting point that can also be finely adjusted according to our sensations until we reach our optimum setting.

I have practiced road cycling for many years but now I am 69 years old and even though I ride about 7000 km (mostly hilly) a year, I have lost power in my legs. I normally use a full carbon BMC bike that weighs only 8Kg and my weight is 56Kg.

My first eBike (ORBEA GainD50) was bought with the purpose of testing and learning a little more about the benefits and advantages of having a certain level of power assistance in the practice of cycling. Especially for people who have reached a certain age and who want to continue enjoying demanding tours.
Bearing in mind that in every route the greatest contribution of power will always come from your human body, it is wonderful to know that on the E-bike you have an energy deposit (battery) which you can use when you need extra power to overcome some momentary requirement of your journey.
The energy available in the battery is a finite resource, and the ultimate goal is to achieve an optimized use that allows us to achieve the greatest distance or the greatest demand.
This is how my first learning is that the <u>optimal use of an E-bike requires proper management of the energy available in the battery.</u>
My first step was then to determine the optimal mapping of assistance levels based on my physical condition and type of routes that I usually practice.

How to customize power assistance levels.
There must be many ways to accomplish this task. In what follows I allow myself to share my thoughts and procedures for it, which have given me good results and have allowed me to properly manage the available energy to make longer and more challenging routes.
First of all let's go to the basics: the practice of cycling is based on the application of power to the cranks of the bicycle to achieve displacement. The speed of displacement will depend on the amount of power applied to overcome forces of nature (gravity, rolling resistance, headwind resistance,...). The greater these forces to overcome, the greater the power that we must deliver to the bottom bracket pedals.
Every human being is capable of delivering a finite amount of power, too much or too little doesn't matter. It is what it is! This power depends on genetics, age, diet, physical condition, environment, hydration,.. so that for a cyclist it becomes like his precious resource.
The power that is measured in Watts (W) can be measured in a sustained manner for different lengths of time. For example, I can deliver 500 W but only for 3 seconds, or I can deliver 160 W continuously for 1 hour, or I can deliver 70 W for 5 hours continuously (see attached graph ,my apologies for the language.) ....



In cycling jargon, the FTP parameter is used to define the level of functional power, theoretically the maximum power delivered in a sustained manner during 1 hour. Each cyclist has his own FTP and it is different for everyone. It is not my purpose to delve into these concepts, for those who so wish I leave the following reference: Training and Racing with a power meter, 2nd edition, Hunter Allen and Andrew Coggan, PhD.
So our FTP is a true indication of the ability of our body to deliver power in the practice of cycling. There are several ways and methodologies to estimate our FTP, it is not the case to explain them here, but from my modest experience in cycling, I have come to the conclusion that knowing our FTP is very valuable if you practice cycling consistently .

Since we already know what our capacity to deliver power to the pedals is , and even better, what is our capacity to sustain that power for 1 hour (FTP), we will see that this capacity, at the end, will serve to move a mass (my body + the bicycle) which is fundamentally affected by the force of gravity. The more mass to move, the more power we must deliver. As our FTP is unique and has a "fixed" value, it is interesting to know how many W I have for each Kg of mass to be moved. This ratio is known as W/Kg and is an indication that provides a lot of information. Studies carried out by Dr. Collang classify these ranges as shown in the attached graph.

Males	Watts per Kilogram (W/kg)
Superior	5.05 and greater
Excellent	From 3.93 to 5.04
Good	From 2.79 to 3.92
Fair	From 2.23 to 2.78
Untrained	Less than 2.23

Females	Watts per Kilogram (W/kg)
Superior	4.30 and greater
Excellent	From 3.33 to 4.29
Good	From 2.36 to 3.32
Fair	From 1.90 to 2.35
Untrained	Less than 1.90

FTP ratings are based on research by Hunter Allen and Andrew Coggan, PhD, *Training and Racing with a Power Meter* (Boulder, CO: VeloPress, 2010).

The cyclist's mass is part of the equation corresponding to each affectation: whether in acceleration, ascent or rolling resistance. Hence, Dr Coggan's studies were based on a huge collection of data from different types of cyclists to try to conclude on what would be a "Power Profile" of our strengths and weaknesses as a cyclist. *"When we began collecting data on various riders, it was because we simply wanted to get a clear picture of the power that different types of cyclists could produce. What levels could be attained by elite pro riders? What could master riders do? What about beginners? From these datasets, we were able to create the Power Profile chart... Dr Coggan, Training and Racing with a Power Meter, page 53.* Thus, for example, a "World class" cyclist like the ones we see in the Tour de France, the Giro d'Italia, or La Vuelta a Espana, are capable of sustaining 6.4 W/Kg for an hour or even more. Or to reach 25 or more W/Kg in a 5 second sprint. While an untrained cyclist will hold perhaps 1.8 W/Kg for an hour or just 10 W/Kg in his 5-second sprint.

That is why to practice cycling in a somewhat orderly and structured way we must start by determining our "Power Profile", in other words where I am in the table and from there I will be able to improve my weaknesses and take advantage of my strengths, and to get a quick idea if we are untrained, if we are good, very good, Pro, or what we are in terms of Power Profile. The important thing is that at tourist cycling we can do a lot.
Let's not forget that all these studies have been developed for professional cycling, but we as amateurs or tourist cyclist can take advantage of them.

We already know our FTP and our Weight those values lead us to know our **W/Kg ratio**.
Let's see how all this helps us to estimate our power assistance levels in our E-bike.

Our objective as a formal and constant tourist cyclist is to place ourselves in the "Good" range. Thus, for example, if a woman has an FTP of 180 W, her mass should be around 60 Kg (if it is less, even better). If we're a bit short, we'll have to compensate with the E-bike's power assistance levels, but let's not forget that the higher the assistance, the shorter the battery capacity lasts. That is why it is also very important that our mass is optimal (each Kg of extra mass will be seen as dead weight and will demand energy from our body).

Highlighting some ideas:

1) An E-bike provides some assistance capability, which must be optimally managed to achieve the longest and most challenging rides possible. But unlike an electric bike, on an E bike the cyclist must provide as much energy as possible during the ride. As mentioned by ngg *"the motor gives as much as the cyclist gives"*

2) It is very important to customize the power assistance levels based on our physical condition and type of rides we want to do.

3) Our physical condition can be described it in terms of our power profile and our mass, through the relationship Watts/Kilograms (W/Kg).

4) From the studies carried out by Coggan, a W/Kg ratio close to 3.5 is good and would allow us to cycle properly. We will use 3.5 as a target number for men or women.

Let's stop at this point and think about the following scenarios:

A) The cyclist has a W/Kg of 3.5 or more. The assistance is not needed, or would help him to go faster, or to make less effort, or to make even more challenging rides than he already can on his own.

B) The cyclist has a W/Kg below 3.5, but not too far. In this case, the assistance levels of the E bike will serve to cover that small difference in its power profile and thus reach the target value of 3.5.

C) The cyclist is well below 3.5 in his W/Kg ratio. So the assistance levels of the E bike will have to supply a lot to cover that difference to 3.5. We can already imagine that in this case the energy stored in the battery will last very short time.

A little more about the mass (kg):
When we refer to mass in the W/Kg ratio, that mass refers only to the mass of the cyclist even though the mass of the bicycle will affects the performance of the cyclist. Let us remember that all these studies, definitions and rules come from the world of professional cycling and there is a UCI regulation in which the minimum weight for a road bike is established at 6.8 Kg, so that all federated UCI cyclists will use bicycles with that minimum value.

In the world of cycling tourism, road bicycles have greater mass; let's say in the range of 8 to 12 Kg. and road E-bike will add even more mass.

Mahle X35 + eco system incorporates an additional mass of 3.5Kg for the hub/motor and battery assembly. In another hand TQ ecosystem has an additional mass of 3.72Kg.

So our amateur road bike now converted to an E bike will have a total mass of 15Kg for the Orbea Gain D50 and 12.4Kg for the 2023 Domane+ SRL6 (56 size).

In short, for our W/Kg calculation we will define Kg value as (cyclist mass+ ebike dead mass+ additional carried mass) :

$$\mathbf{Kg = (m_c + m_d + m_a);}$$

Let me have the following scenario: 56 Kg cyclist mass, FTP= 130W, using a Domane+ SLR6 and carrying 2 Kg (water bottle, food, outfit, battery extender and tools) .

Kg = (56+12.4+2) =70.4 (no battery extender)

To have a good cycling performance we will need W/Kg = 3.5; so, for this example W=246 watts is the total max power needed. We will call this value as **"Equalized Power".**

When we ride a bicycle we are going to require power to move, and it will be affected mainly by three forces to overcome: gravity, rolling resistance and aerodynamic resistance. See the link for some details:
https://www.slowtwitch.com/Tech/The_Physics_of_Moving_a_Bike_163.html

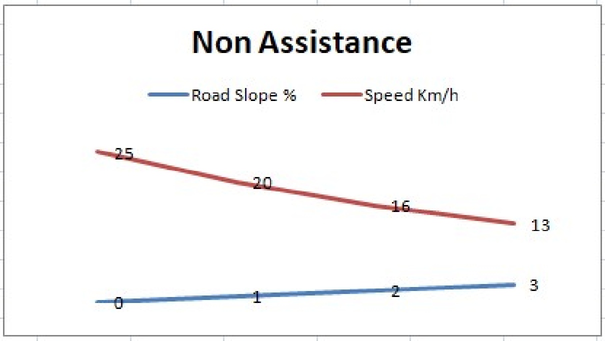
My experience using E Bike led me to customize the levels of assistance based on **the slope of the route and the speed** at which I want to travel. I have concluded and propose the following slope ranges.

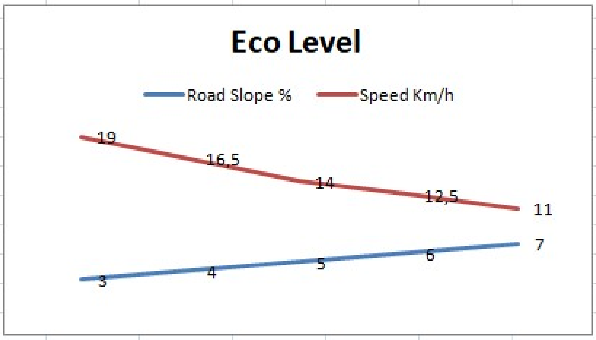
SLOPE CRITERIA

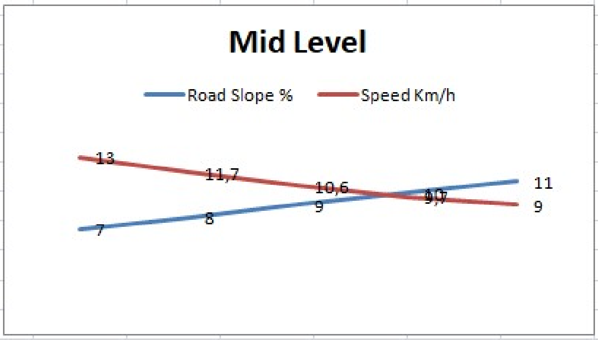
Assistance Off (no assistance) when the route slope is **negative range or from 0% to 3%**.
ECO Level when the slope of the route is in the range of **3% to 7%**.
MID Level when the slope of the route is in the range of **7% to 11%.**
MAX Level when the slope of the route is in the range of **11% and above.**

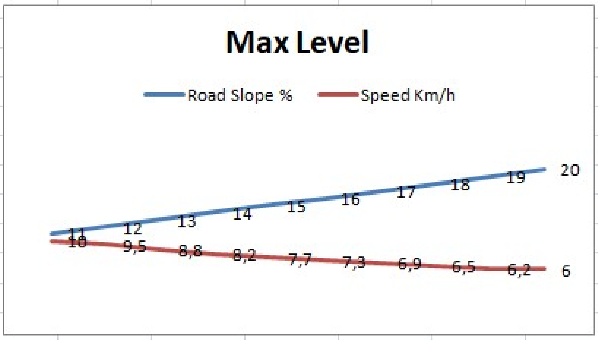
SPEED CRITERIA

I need to establish the speed ranges at which I want to move on those slopes. Here our favorite style comes into play, but always finding a balance so as not to consume a lot of battery power.
My proposals for speeds that are pleasant for a tourist cycle are around the following:









To finish the modeling this methodology we need to return to the concept of FTP that we discussed earlier and that we could say is the "***personal signature***" of the cyclist from the point of view of his physical condition. No two cyclists are the same. There is no good or bad FTP, it is as it is and from there we must build our personalization of the levels of assistance.
It is not my purpose to delve into how FTP is measured, there is a lot written about it.

We can see from the following table of Dr. Coggan's studies that by providing 80% of our FTP power, we can make long-term runs since we will be between the Endurance and Tempo zones.

Level	Name/purpose	% of threshold power	% of threshold HR	RPE	Time
1	Active recovery	≤55%	≤68%	<2	1.5hours
2	Endurance	56-75%	69-83%	2-3	2.5 hours to 14 days
3	Tempo	76-90%	84-94%	3-4	30min to 8 hours
4	Lactate threshold	91-105%	95-105%	4-5	10 - 60 min.
5	VO_2max	106-120%	>106%	6-7	3 - 8 min.
6	Anaerobic capacity	121-150%	N/a	>7	30 sec. - 2 min.
7	Neuromuscular power	N/a	N/a	(maximal)	5 - 15 sec.

Knowing that cyclist is able to provide just 80%xFTP, we will call "**Assistance Max Power**" the difference **(Equalized Power – FTPX80%)**.

For the scenario Assistance Max Power = 142 W.

Assistance Max Power is the maximum power that we are going to demand from the EBike power system during the most adverse conditions of our route, that is, slopes greater than 11%.
But for smaller ranges of slopes we will demand less power, so we can start with the following distribution:

Up to 3% road Slope: No assistance power, just cyclist **FTP**
From 3% up to 7% road Slope: **(Assistance Max Power) x 50%**
From 7% up to 11% road Slope: **(Assistance Max Power) x 75%**
From 11% up to 20% road Slope: **(Assistance Max Power) x 100%**

So, to finish the 56Kg cyclist scenario, with 130W FTP, using
Domane+ SLR6
Carrying +2 Kg
100 meters above sea level
No headwind
Clincher tires
Position on hoods

ECO assistance level must be personalized to 70 watts.

MID assistance level must be personalized to 106 watts.

MAX assistance level must be personalized to 142 watts.