# VITTORIA WHITE PAPER

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# BICYCLE TIRE CASING MATERIALS AND PROCESSES

## COMPOSITION AND BENEFITS OF NYLON, COTTON & SILK CONSTRUCTIONS

**KEN AVERY**

**SENIOR VICE PRESIDENT, PRODUCT DEVELOPMENT**

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**FOR MANY, IT IS ASSUMED THAT BICYCLE TIRES ARE SIMPLY MADE OF RUBBER. AFTER ALL, THE RUBBER COMPOUND THAT TOUCHES THE ROAD IS OFTEN THE MOST OBVIOUS CHARACTERISTIC OF THE TIRE ITSELF.**

**HOWEVER, ASSUMING SO OVERLOOKS THE VERY FOUNDATION OF THE TIRE (THE CASING), AND IGNORES THE MATERIALS THAT ARGUABLY HAVE THE MOST PROFOUND EFFECT ON PERFORMANCE, FEEL, AND DURABILITY, WHICH ALLOW THE RUBBER TREAD TO DO THE WORK IT'S DESIGNED TO DO. IT'S AN EASY MISTAKE TO MAKE, AS THE MATERIALS FOUND WITHIN THE TIRE CASING ARE NOT VISIBLE TO THE NAKED EYE.**

**TO EXPLORE THE RELATIONSHIP BETWEEN CASING MATERIALS AND USE, THE FOLLOWING WHITE PAPER WILL DIVE INTO THE MOST COMMON MATERIALS AND APPLICATION METHODS USED TO MAKE PNEUMATIC BICYCLE TIRE CASINGS, COMPARING THEIR STRENGTHS AND WEAKNESSES, AS WELL AS THE IDEAL APPLICATIONS FOR EACH.**

# INTRODUCTION

In simple terms, to build a pneumatic bicycle tire you must have a material base to serve as a foundation. This material must be lightweight yet strong, supple yet puncture resistant, and it must be able to withstand high pressure with minimal elasticity. It is what forms the tire casing, which is simultaneously tasked with containing the pressurized air, as well as supporting (and connecting) the other elements of the tire, such as bead and tread.

A tall order indeed.

As we reviewed in our previous White Paper (Bicycle Tire Types and Systems), bicycle tires have traditionally taken the form of clincher (whether tubed or tubeless) or tubular style construction. With clincher systems holding tires in place with rim-wall/bead interfaces, and tubular systems being secured to specific rims via glue, these systems employ vastly different production processes to achieve their desired results. This often necessitates materials that are as different as the casing types themselves.

We, as cyclists, are always striving for ways to improve the simple machine, and lean heavily on material advancements to that end. Products are often made from exotic materials such as carbon fiber, graphene, titanium, aluminum, and various other alloys, to minimize weight while maximizing performance. When it comes to tires, the topic of casing materials is no different.

While some of these materials are the product of space age technology, others are as familiar as the covers on your bed. In the following sections, we will dissect the materials most commonly used in bicycle tire casings, and highlight the strengths, weaknesses, and applications for each.

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# SECTION 1. PART 1.
# PIECES OF THE PUZZLE

→ In order to review the materials used in tire construction, let's first briefly dissect the components of clincher and tubular casings.

Both share a cloth based casing material, rubber tread, and often use anti-puncture layers under the tread area. Occasionally, both will employ additional layers or other forms of inserts to manipulate sidewall feel or durability. However, in terms of differences, the largest has to do with the remaining components, and how they affix the structure to a wheel.

On each edge of the clincher casing is a lip, known as a bead, which provides a secure interface for where the tire meets the rim. However, on a tubular style casing, the tire is affixed to the rim via glue, so in place of a clincher bead style interface, a tubular casing uses base tape which provides a smooth and uniform surface for the glue to bond to. Both methods necessitate specific materials to achieve the desired result, and add to the list of materials needed to produce a full line of bicycle tires.


**FIGURE 1.** An example of clincher construction.


**FIGURE 2.** An example of tubular construction.

# SECTION 1. PART 2.
# CASING CLOTH

As pneumatic bicycle tires have been around for over a century, product designers have had ample time to address needs, and apply solutions to increase both performance as well as dependability. While this time has spurred evolution in many ways, some tried and true materials and methods are still widely used, and have stood the test of time.

In this section, we will review commonly used materials for each component, as well as why each are chosen.

### CASING CLOTH

The casing cloth material is arguably the most significant component of the system. This cloth is the crux of the story when it comes to defining a casing type, and largely defines the ride quality, as well as resistance to abrasion and punctures.

Therein lies the conundrum, as traditionally riders have been forced to choose a casing material which only can provide one, rather than both of these valued traits, regarding comfort and durability. However, as we will see below, improvements in production methods have narrowed this divide.

The most common materials that casing cloth has been traditionally made from are nylon as a synthetic option, with cotton and silk as a natural fiber options.

For the purpose of this White Paper, we will therefore concentrate on these three materials. However, just as a rain jacket, a bed sheet, and a scarf differ in both use and feel, so do these casing types.

### NYLON

Nylon casing tires are the most common in modern times, and span the full range of both use and price points.
Broadly speaking, the vast majority of simple black sidewall bicycle tires observed in use are likely supported by nylon cloth.

### COTTON

Cotton casings have been utilized in one form or another for over 100 years. Modern cotton casings are typically used for high end racing applications, especially in Road, Gravel, and Cyclocross categories. While they are available in a range of colors, the traditional cotton casings are naturally tan, and are often identified quickly by this trait.

### SILK

Silk casings as typically found in Road or Track cycling applications, at the very high end of the market spectrum, specifically designed for race use. While it may be rare to see a silk tire casing while out on a group ride, the advantages of silk in certain competition applications are undeniable.


**FIGURE 3.** Difference between nylon fibers, cotton fibers and silk fibers.

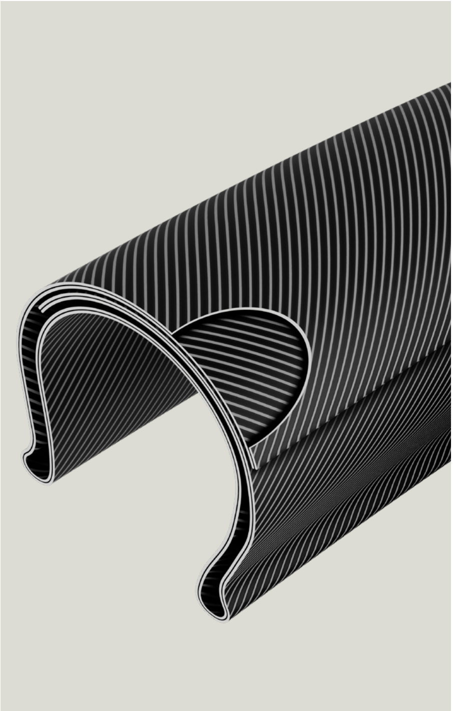

**FIGURE 4.** Zoomed nylon casing.

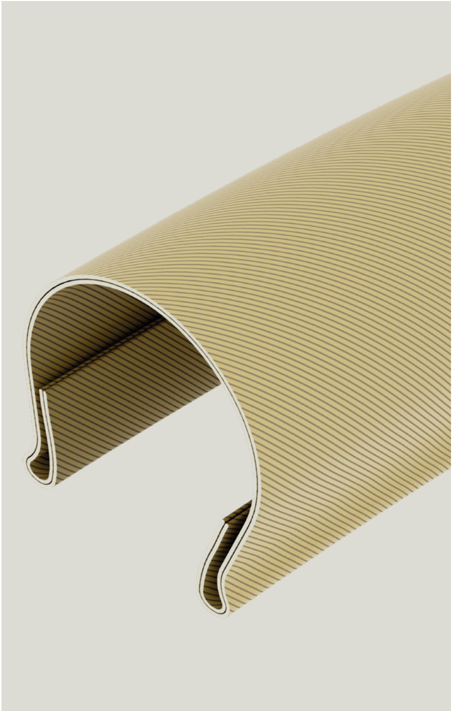

**FIGURE 5.** Zoomed cotton casing.

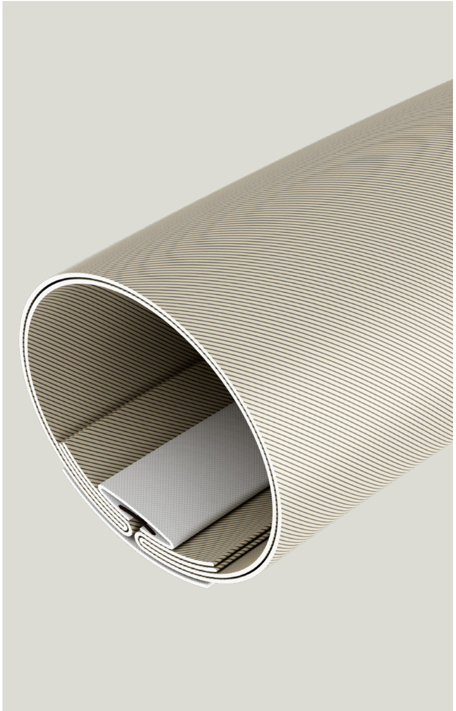

**FIGURE 6.** Zoomed silk casing.

## SECTION 2. MATERIAL PROPERTIES IN CASING PRODUCTION

### NYLON

Nylon is used to form a synthetic fiber, which is then woven into cloth, forming the basic casing construction. This cloth is then cut such that the threads oppose the eventual rolling direction in a deliberate angle (often at 45-degrees for bicycle tires). Rubber is then pressed into the fabric using high heat and pressure, impregnating the cloth.

This rubberized nylon cloth is then cut to a specific width for the individual tire size and width.

In order to form the shape and structure of the tire, in the case of a clincher, bead wires are then rolled onto the edges of the cloth, and encapsulated. A specific width belt of rubber is then placed in the center of the material, which will eventually form the tread. At this stage, any remaining items such as sidewall protection, sidewall logos (known as "hot patches"), or other items such as reflective stripes are applied to the casing material. The construct is then placed into a sealed clam-shell shaped mold, and along with a high level of heat, a bladder will press the construct into the negative tread, while simultaneously melting the individual components together.

This process is known as vulcanization, and is used widely throughout the industry, for tires of all types.

## COTTON

Similar to nylon casing construction, when using cotton as the substrate, the fibers are also woven into a cloth, and ultimately oriented in a deliberate angle relative to the rolling direction.

However, consider that the cotton fibers used are much thinner compared to nylon fibers used, which produces less of a valley between the fibers. Therefore, rather than impregnating the cloth with butyl based rubber, latex is used, as it is far less viscus in liquid form. This allows the latex to penetrate into the tighter fabric fibers of cotton, forming the final substrate of the casing. From there, if the cotton tire is vulcanized, the process is the same as a nylon tire.

Yet, as the use of cotton in tire casings pre-dates nylon, often times cotton is still used in the time-proven "hand made" method of tire construction, which is non-vulcanized. This is especially popular in tubular construction, but is also used in certain clincher applications.

In this method, the tire maker will create the cotton casing (whether tubular or clincher) using the latex impregnated cloth, and then bond a tread cap to the casing, using an adhesive.

## SILK

The method for silk casing production most closely resembles that of cotton, as described above, as does the inherent material advantage and practical applications.

Like cotton, silk naturally has very thin fibers (translating to a high TPI), allowing for increased suppleness and reduction in rolling resistance. However, where cotton is a staple yarn, made from twisting short fibers together, silk is a continuous protein filament yarn.

This factor is what gives silk its luster and high tensile strength.

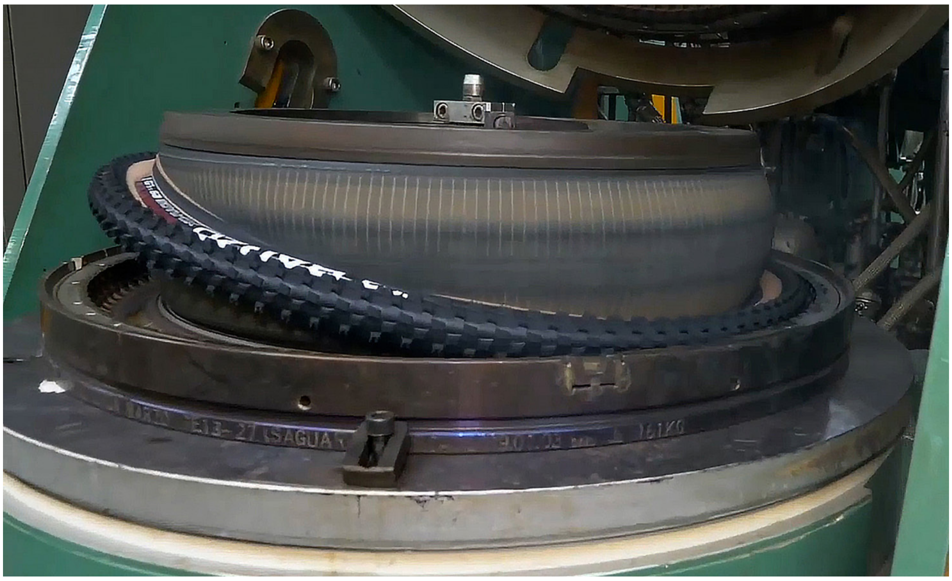

**FIGURE 7.** Example of a tire in a mold.


**FIGURE 8.** Production of handmade cotton casing.

Often, the silk casing is lighter than the cotton casing, and has an even lower measured rolling resistance.

Depending on the casing construction, silk casings can also be made as strong as the cotton version, allowing for a fast, strong, and supple combination of characteristics.

Historically, this combination comes balanced with a higher cost, but such is the price of performance.

In the next section, we will take a further look into the pros and cons of each material, as well as method.

**FIGURE 9.** Silk casing tubular on a wooden track.

# CHOOSING THE CORRECT CASING MATERIAL

As with most materials, there are pros and cons to each, which are often the reasons multiple options exist within manufacturing in the first place. Bicycle tire manufacturing is no different, and as various disciplines have evolved, so to have material applications.

To begin, material choice is all about catering to the goals of the product, and therefore in each discipline, the goals will be slightly different. For example, some tires may place speed as the ultimate goal, while others may place durability or grip at a higher value. In the end, the sum of the parts will dictate whether that goal is met, and as we've covered in the section above, the casing material is the core of the system.

One exaggerated use case example would be in a track tire, where speed is the key performance indicator. In track cycling, racers compete for time or distance depending on the sub-event, and due to the nature of an oval track, are limited in terms of dynamic cornering. These tracks are typically groomed wooden surfaces, devoid of the typical road hazards that may be found on roads. These hazards would normally include objects which may cause traditional sidewall abrasion or punctures from debris, however, since this is a controlled surface, tire makers are free to develop products without the need to cater to this parameter.

Consequently, to achieve the desired speed, the material which traditionally returns the lowest level of rolling resistance is chosen. In this instance, high TPI (Thread Per Inch) cotton is often chosen, as it is extremely flexible. This flexibility allows the tire to deflect less from surface imperfections, and as a result, has shown very low levels of rolling resistance. To add to the flexibility, a thinner tread band is also used, as again, mileage and durability are not KPIs in this scenario.

The net result is a championship winning casing construction for this intended use. However, it's worth noting that if this exact tire were to be used outside, in normal conditions, the results would be quite different, as again, the environmental parameters would also be different.

Conversely, at the other end of the product use spectrum is Enduro and Downhill mountain bike racing.

In these disciplines, riders race down extremely technical tracks, strewn with rocks and roots, across various types of dirt, and in every weather condition possible.

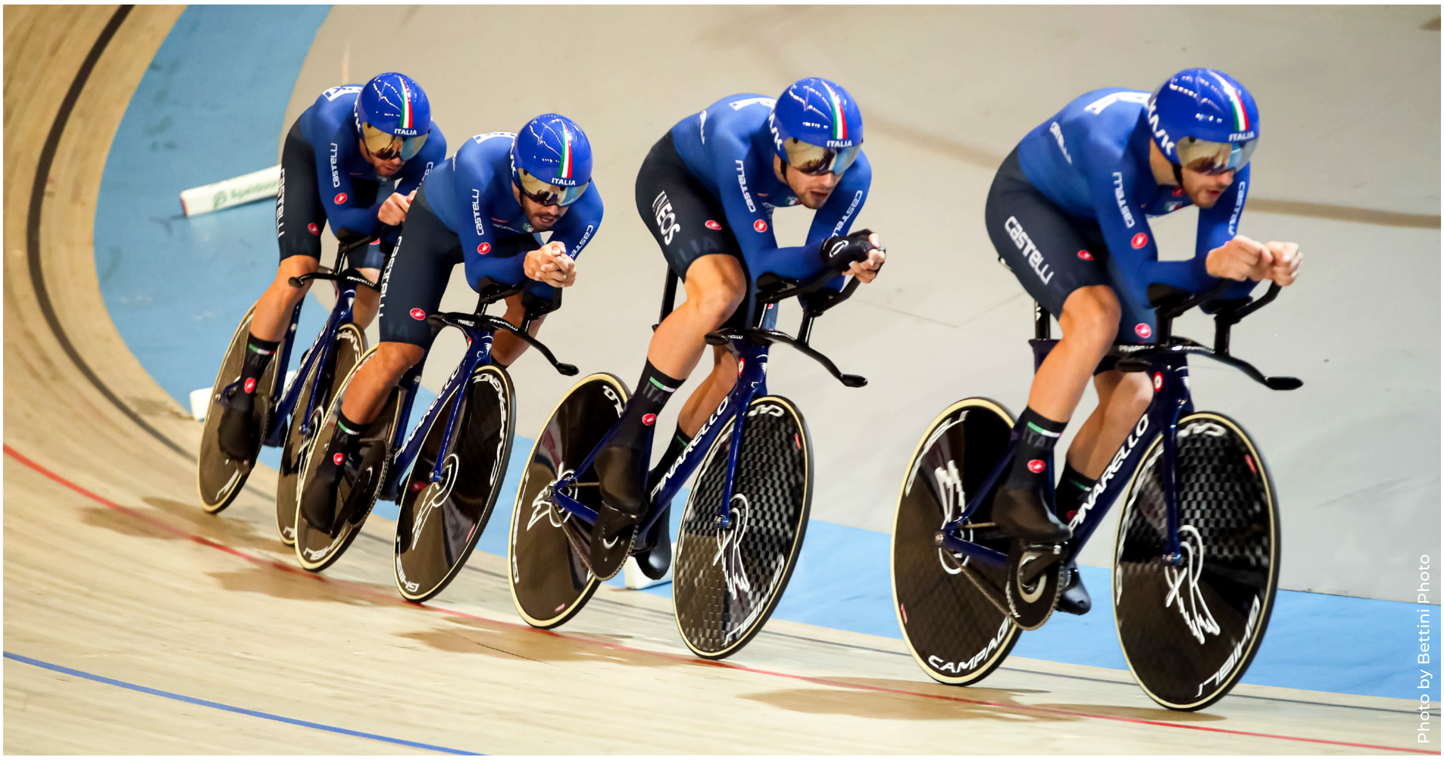


**FIGURE 10.** Riders on a wooden track surface.


**FIGURE 11.** Mathieu Van Der Poel winning on cotton casing tires.

Speeds, as well as impacts, are high. Downhill is a one-run race format, where Enduro is a multi-stage/cumulative time format.

As both are timed events, a tire failure will almost always take a racer out of contention. Bottom line, if there were torture tests for tire casing materials, these two disciplines represent the worst.

Here, grip is king followed by durability, and while pure rolling resistance does matter, it is certainly a distant third KPI. You may wonder, as a racing use case, why isn't rolling resistance a higher ranked KPI?

The answer is logical, but complex. In these categories, control is what dictates speed. Rider inputs are calculated in a fraction of a second, and as a result, rider trust also is a factor. There can be no control, especially at high speeds, if grip is not maintained. Likewise, if the tire is not stable (during deformation), or does not remain inflated, control will certainly be compromised. Inherently, a rider who trusts both the grip and the durability of their tires will go faster than a rider who has fast tires which may not provide a high level of grip, or which may flat as a result of impacts.

For these reasons, tire casings designed for the Enduro and Downhill categories are typically made from thicker (lower TPI) nylon, and feature robust reinforcements to counteract both impact, as well as abrasion.

These tires are more resistant to lateral forces, and are designed to be used at extremely low air-pressures.

The above examples are just two, out of a seemingly endless array of casing material applications, engineered to reach a specific performance goal. While other more closely related disciplines may feature a more similar construction, these polar opposite examples underline how critical the casing material choice is when building a tire. Simply put, a track tire with a thick nylon casing would roll too slowly to reach the intended goal, while an Enduro or Downhill tire with a super flexible cotton or silk casing would not offer the stability or durability needed for those events.


**FIGURE 12.** A rider on a technical enduro course.

Photo by Dan Hearn

# SECTION 4.
# THE FUTURE OF BICYCLE TIRE CASING MATERIALS

→ Which came first, the innovation, or the use?
Did a specific use spur the innovation, or did some clever innovation allow for an expanded use?

Whichever way the path was formed, for such a simple machine, it's staggering to watch the technology side of the bicycle continue its explosive growth. What once seemed the stuff of science fiction is in many ways here, and likely already on a dealer showroom. Technologies such as wireless shifting, anti-lock braking, and smart e-bikes were just fantasies not long ago. It seems as though each year performance records are broken, products are made even lighter, and riders are going further than ever before. Beyond that, as urban environments continue to become more densely populated, people are turning to the tried and true bicycle as their simple form of healthy, clean, and efficient transportation.

Perhaps this should be of no surprise.
We are at an interesting time in history, where bikes have become so good, so efficient, and honestly so useful, that now the innovation may begin to enable the use. In fact, in many cases, this is already happening within the bicycle tire industry.
If we look at the future of casing material in two ways, through performance and utility, we made have a similar contrast to the race examples used in Section 3.

**FIGURE 13.** A rider in city traffic.


**FIGURE 14.** Rubber tree with bucket.

## → PERFORMANCE

No matter what technological innovation is developed, the basic physics of how performance is measured won't change. However, the approach to measuring an ever higher bar of performance is now different, and in the future will continue to be more so.
In the future, not only will tires become faster across all disciplines, they will also increasingly become more eco-friendly without sacrificing the performance that defines them.
The old adage of "speed, grip, durability – pick 2" is no longer acceptable to engineers, or consumers for that matter.

Performance tires of the future will simultaneously improve upon traditional performance metrics, last longer, and while use increasingly sustainable materials as well as methods of production.

In terms of tire casing, this can mean using traditional natural fibers (such as cotton or silk) in new ways, by taking lessons learned from nylon casing production, and applying them to create an improved version.

**FIGURE 15.** Marianne Vos in aero position.


Photo by Bram Berkien

Fine tuning the use of natural rubber and latex, and applying them to innovative casing structures, will positively impact both speed and durability.

Such an application within the casing will produce faster tires, but also tires which last longer, and in turn reduce waste. Where super-performance is needed, this increase in durability will allow tire casings to be thinner, and ultimately more flexible, indirectly leading to less weight, as well as a reduction in rolling resistance.

## UTILITY

As bicycles are increasingly used for activities outside of fitness or pleasure, the approach to achieving the goals of utility focused bicycles also changes when tire casings are considered.

The historical default approach to this category has always been to take a tire designed for normal use, reinforce it in some simple way (by adding a ply or insert), and testing the new limits. However, many times this approach yields negligible gains at best, or at worst, gains which come with hefty weight or complexity.

For tires of the future, outside the box thinking will be applied to this category, and will borrow both materials and technologies from other industries. As many of these utility bikes are e-power assisted, the bikes themselves will be heavier, faster, and make more torque than solely human powered bicycles, all while being designed to carry the heft of cargo loads. In many ways, these bicycles will resemble small motorcycles, but with intricate integrated racks and storage solutions. These traits will necessitate reinforcement in terms of stability and blow-off resistance, while maintaining the reasonable weight and rolling efficiency of normal bicycle tires. To produce a tire casing which can handle this challenging list of KPIs is no small feat.

**FIGURE 16.** An example of an e-cargo bike.

Fiber technology and coating techniques will be a critical part of the solution, and will likely come from lessons learned in the military, ballistic, and aerospace realms, which will then be blended with the known methods of tire casing production. Adding to this, the increasing need and desire to produce an eco-friendly casing, and this becomes quite a robust design challenge for the future.

## SUSTAINABILITY

In the never ending quest to further optimize both performance and utility, as functions of expanded innovation and use, it is impossible to not consider sustainability as a target for all.

By design, the bicycle is perhaps the most simple form of sustainable transportation, so it makes sense to then also incorporate sustainable materials and construction methods into the very machine which enables this use. Elementally, when looking to the components of a tire, using natural materials like cotton, silk, and even natural rubber bring us closer to this ideal. However, in the future, for the system to truly be sustainable, we must close the loop, and consider sustainably sourced materials for the remainder of the tire construction, environmentally responsible production facilities, as well as a widely supported system for recycling used tires. The future is now, and already manufacturers are embracing this direction into increased sustainability, both in pre-production material sourcing, as well as post use. This means that as the previously discussed performance and utility continue to evolve, so too does the reduction of environmental impact. We are truly at an inflection point, where bicycles have never been more capable, yet also so critical in their role within daily life. By adding increased levels of sustainability, we continue the evolution of the bicycle into the new realm.

If we've learned anything from history, designers, engineers, and even enthusiasts will stop at nothing to improve upon this simple machine we call a bicycle. As we've discussed, improvement can come in many forms, from performance, to utility, and now sustainability. The optimist's prize for winning this design challenge, is the increased lifestyle integration of human powered mobility which these optimized tire casings will allow, while further increasing the speed, grip, and durability of performance bicycle tires as we know them.