<u>Defining Bow Performance</u>

<u>What is performance?</u>

A stickbow is really nothing more than a simple spring. When the archer pulls the string back the spring is loaded and energy is stored. At the loose, the stored energy is transferred into the arrow, propelling it forward. We just defined performance! The two most important components of a bow's performance are <u>how much energy is stored</u> when the bow is drawn and <u>how much of that stored energy goes into the arrow</u> instead of being lost in the form of waste energy. Let's discuss each component a bit more.

<u>Stored Energy</u>

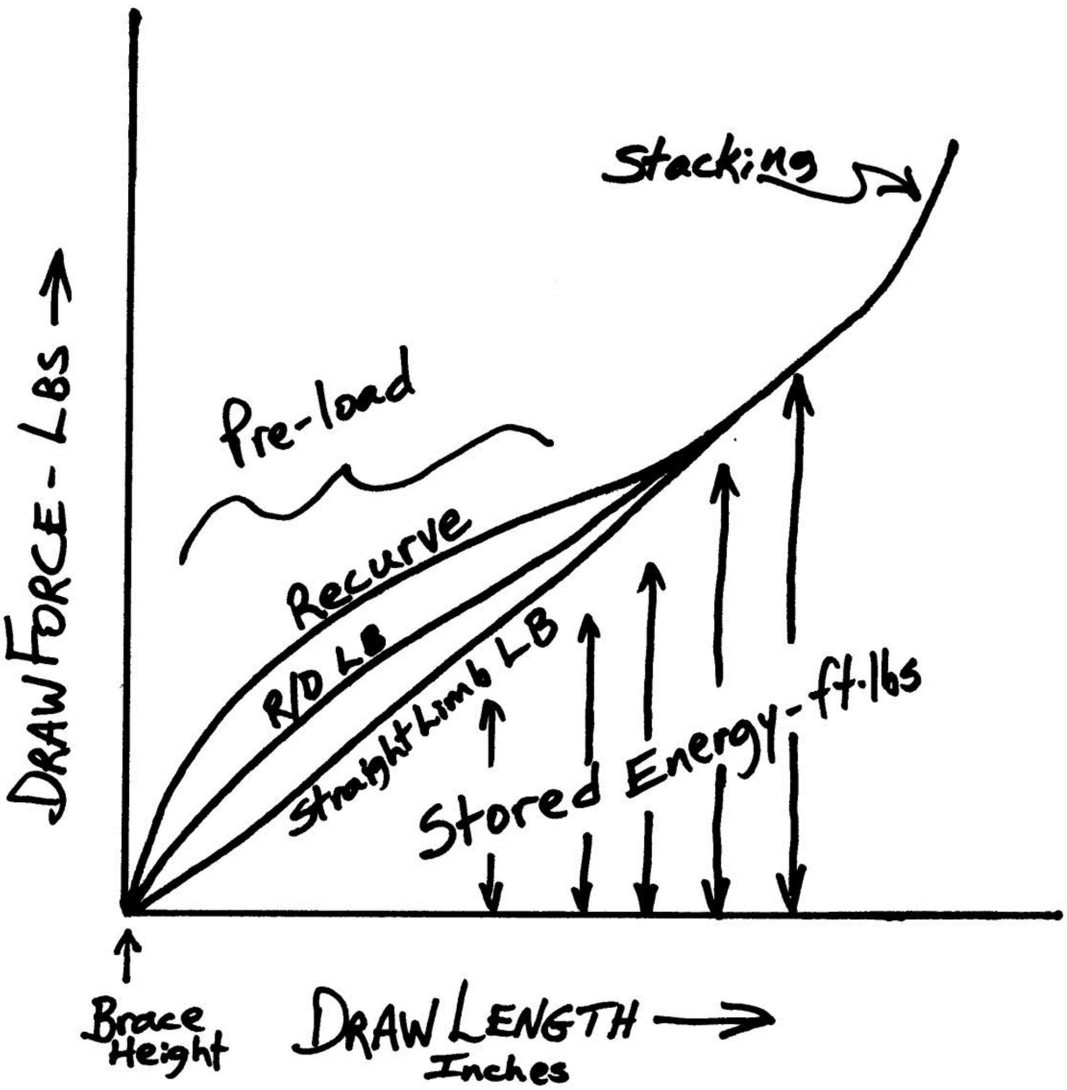
How much energy, measured in foot-pounds (ft-lbs), a bow stores is a direct function of its design. Straight-limbed longbows store less energy than reflex/deflex (R/D) longbows. R/D longbows generally store less energy than recurves or hybrid longbows. In a way you can think of how much energy a particular bow stores as sort of a "storage efficiency". People who test lots of bows use a ratio of Stored Energy per Pound of Draw Force, or SE/PDF. This ratio is a handy way of comparing how efficiently one bow design stores energy versus a different design.

Determining how much energy a bow stores is fairly straightforward. The bow's Force/Draw (F/D) curve (draw weight per inch of draw length) must be <u>accurately</u> determined (more discussion about the importance of accurate measurements comes later). To do this accurately, a bow must be mounted into some sort of fixture that holds the bow securely. Using an <u>accurate</u> scale (there's that accurate word again!) and pulley system, the bow's draw force is measured from brace height to full draw.

Plotting the draw force at each inch of draw allows the person testing the bow to see what the F/D curve looks like. The area under the F/D curve is the amount of energy stored by that particular bow. Since many F/D curves are not straight lines, calculating the stored energy requires a point-by-point summation of the area under each data point. To save time we use a spreadsheet program given to us by Norb Mullaney, the recognized authority of bow testing throughout the industry, to do this summation.

The following drawing illustrates three different F/D curves for three different bow designs. Intentionally exaggerated for illustrative purposes, the relationship of how different bow types compare with one another is correct. Understanding the indisputable fact that a bow's design impacts the amount of energy it stores is fundamentally important. Take a moment to look at the following drawing.

FORCE/DRAW



Before discussing each type of bow let's define a couple of terms. "Pre-load" is the term frequently used to describe a bow that stores more energy early in the draw. Recurves and hybrid longbows typically have the most pre-load. That's why they store more energy than other bow designs. The pre-load area, or F/D "hump", is identified on the drawing. Another term to understand is "stacking". A bow stacks when its draw force starts increasing rapidly. In stickbows this typically happens out at the end of the draw. A bow that's increasing in draw weight 4-5 pounds per inch at the end of the draw versus one that's increasing only 2-3 pounds per inch at the same draw point is much more uncomfortable to draw and shoot. It's stacking.

Take note of the shape of each bow’s F/D curve. This is a critical factor in bow performance. If a particular bow design stores less energy it has less energy to give to the arrow – plain and simple. Pre-load is very important to bow performance. It increases the amount of stored energy dramatically. Bows that don’t have pre-load don’t have good SE/PDF.

What this means is that all 60# bows are definitely not equal! A straight-limbed longbow with a SE/PDF ratio of .85 (30” AMO draw) stores 51 ft-lbs of energy. A typical well-designed hybrid longbow or recurve will have a SE/PDF ratio of .98 (also at a 30” AMO draw), which means that particular 60# bow stores 58.8 ft-lbs. A bolt-down Dryad ACS hybrid longbow stores even more – 60.6 ft-lbs. The latest bolt-down ACS recurve we’re working on at Dryad stores 63.6 ft-lbs. That’s a lot of difference in stored energy! That stored energy, if delivered efficiently to the arrow, results in better performance. But that’s another couple of chapters ahead.

Here we must also address the differences in bolt-down bows versus ILF bows. By its very nature, ILF is a compromise – an excellent compromise but a compromise none the less. Every limb is supposed to fit on every riser. That means that a limb optimized for one particular riser might not be equally optimized on another one. The combination of risers and limbs is what controls overall bow geometry. And brand X limbs on brand Y riser might or might not be optimum. They will work, and they will shoot. But there’s no guarantee that a particular combination of limbs and risers will equal the performance of an optimized bolt-down bow. You give up a little performance in exchange for the flexibility of using any combination of limbs and risers.

Just a quick word about SE/PDF measured at different draw lengths. Long draw lengths allow lots of energy to be stored in the bow’s limbs. Shorter draw lengths, even at the same draw weight, store less energy. Just draw two F/D curves with the same draw weight but different draw lengths and it will become immediately obvious that the shorter draw has less area under the curve. It has to! Lately we have been testing quite a few bows at 24”, 26”, 28”, and 30” of draw (<u>accurately</u> measured as per AMO standards). A reasonable rule of thumb based on these tests is that SE/PDF goes down about 3.5% per inch of draw reduction between 30” and 26”. Below 26” and the difference is even greater.

So, what does this mean? For example, let’s consider two identical recurves, one being drawn to 30” and the other one being drawn to 26”. For purposes of this illustration the recurve being drawn to 30” has a SE/PDF ratio of .98. The identical recurve being drawn to 26” has a SE/PDF ratio of 0.84 (.98 – 4*.035). Furthermore, let’s assume that each bow has a draw weight of 60 pounds at their respective draw lengths. What this shows us is that the typical top-of-the-line recurve drawn to 30” stores 58.8 ft-lbs of energy (.98*60#) while the same recurve drawn to 26” stores 50.4 ft-lbs (.84*60#). It is very simple to calculate the impact this has on arrow velocity (assuming each bow’s dynamic efficiency is exactly the same). But we’re getting ahead of ourselves. We’ll talk more about dynamic efficiency later.

Please remember that the illustration of F/D curves for three types of bows is not absolute and 100% true for each and every bow in the world. After having tested many different bows from many different sources we are comfortable that the illustrated relationships generally hold true.

The following table summarizes what we have learned about how different bows store energy:

Bow Type	SE/PDF @ 26"	SE/PDF @ 28"	SE/PDF @ 30"
Straight-limb LB	.71	.78	.85
R/D longbow	.78	.85	.92
Recurve/hybrid	.84	.91	.98
Dryad ACS LB	.87	.94	1.01
Dryad ACS Recurve	.92	.99	1.06

A couple of things need to be said in order to qualify the values quoted in the above table. First and most important, these are generally accurate and are based on actual measurements taken on the various types of bows. Some bows of that type may have more or less SE/PDF, so please don't think that the above numbers precisely match every single bow out there. While the values are reasonable some bows will vary slightly. And secondly, an alternate way to represent the values would be to quote a range for each type of bow at each draw length. But to do that would become needlessly burdensome. The values in the above table are reasonable, based on actual measurements taken on a variety of bows, and are therefore entirely adequate for purposes of discussing bow performance.

Dynamic Efficiency

The other very important variable in understanding a bow's performance is its dynamic efficiency (DE). DE for any particular bow is the ratio of the kinetic energy of the arrow after it leaves the bow divided by the stored energy, which was explained previously.

Arrow kinetic energy is determined by accurately measuring the speed of an arrow by use of a chronograph. The formula for arrow kinetic energy (in ft-lbs) is shown below:

KE (ft-lbs) = (arrow weight in grains)(arrow velocity in fps squared)/450,240

Note that the arrow weight in grains must be accurately measured, also.

The only way to accurately measure the speed with which a bow shoots an arrow is to use a shooting machine. A near infinite number of variables are introduced when human hands hold the bow and draw the bow and release the string. Two people shooting the same bow with the same arrow and supposedly drawing it to the same draw length each time can EASILY see speed numbers that are 10 fps or more apart. Any data not collected with a shooting machine is probably worthless for bow comparisons. Sorry, but there it is.

Using a shooting machine which holds the bow in exactly the same way each time and which draws the bow string the exact same distance each time and which releases the bow string exactly the same each time results in arrow speed readings which vary less than 1fps of each other - time after time after time. That kind of accuracy is for all practical purposes impossible to achieve by hand. Any time someone provides you with bow performance numbers not obtained with a shooting machine, and preferably by an independent third party using a shooting machine, you should take the numbers with a large grain of salt.

Dynamic efficiency, just like SE/PDF, is a function of bow design. Many variables affect a bow's dynamic efficiency, but the largest single factor that we've been able to find is the weight of the bow limb. Consider two top-fuel dragsters that are exactly identical in every way (horsepower, etc.) except one weighs 5000 pounds and the other one weighs 2000 pounds. Which one do you think will be quicker to the quarter mile pole? I don't know about you, but my money would be on the lighter dragster!

Earlier we said a stickbow was nothing more than a simple spring. For stickbows that have heavy limbs, a larger portion of the energy stored (SE/PDF) will be wasted in accelerating the dead mass of the limbs forward back to brace height upon the loose. If you can store the same amount of energy while reducing the mass of the bow's limbs then more of that stored energy HAS to go into the arrow where it belongs.

That's what the ACS design does. By using a proprietary and patented cross-sectional design (U.S. Patent No. 6,718,962), here at Dryad we are able to build limbs that are much stronger and stiffer. That enables us to use much less material in the limb resulting in limbs that weigh between one-third and one-half as much as conventionally-constructed bow limbs.

We use limb <u>molds</u> instead of limb forms. Our limbs are actually molded three-dimensionally instead of two-dimensionally in a form. Building an ACS limb isn't easy and requires precision and extreme attention to detail. However, the benefits in performance make the extra effort worthwhile.

Dynamic efficiency of any bow varies with arrow weight. A heavier arrow absorbs more of the stored energy than a lighter arrow. Previous testing done on ACS bows by Norb Mullaney (renowned bow tester, author, and the man who wrote the ASTM standards for bow testing), dynamic efficiencies range from just over 80% to 88% as arrow weights increase from 360 grains to 700 grains. The measured DE of all bows will be higher with heavier arrows than with lighter arrows. But the fact remains that given the same amount of stored energy the more efficient bow will cast any arrow faster than a bow with lower efficiency.

To compare the dynamic efficiency of one bow type to another it is necessary to measure arrow speeds based on some consistent arrow weight, expressed as an accurately-measured grains per pound of draw weight. For purposes of this discussion the numbers quoted in the following table are all measured from bow tests in which each bow was shot with an arrow that weighed 9 grains per pound of draw. Using the range provided by Norb it is reasonable to conclude that each type of bow's dynamic efficiency will vary as much as plus or minus 4% from the 9 grains per pound number as arrow weight goes up or down.

As previously mentioned, dynamic efficiency varies from one type of bow to another. The following table provides reasonable numbers for various types of bows at arrow weights of 7, 9, 11, and 13 grains per pound.

Bow Type	**DE % (7)**	**DE % (9)**	**DE % (11)**	**DE % (13)**
Straight-limb longbow	68	70	72	74
R/D longbow	73	75	77	79
Typical recurve/hybrid	73	75	77	79
Dryad ACS CG hybrid longbow	82	84	86	88
Dryad ACS top-end recurve	80	82	84	86

One other interesting thing to note about dynamic efficiency: it varies very little between 26" to 30" of draw. Generally no more than 1% has been observed. Therefore, as long as consistent arrow weights are used (X grains per pound of draw) for each draw length, the dynamic efficiency for any particular bow doesn't change much.

The same qualifications need to be offered for the above table as were stated for the SE/PDF table. The numbers in the above table for the non-ACS bows are based on various observations and bow tests, and are representative of that class of bow but not of any particular bow. Again, for the purpose of discussing performance differences between bows the above numbers are representative and therefore entirely adequate for drawing general conclusions.

Making Accurate Measurements

Every variable that can be minimized is important when comparing one bow with another. Obviously when shooting a bow through a chronograph a shooting machine is required. But what about the other things that can have an effect on a bow's measured performance? Let's discuss just a few of them. Remember – any single inaccuracy can and most probably will result in data that's not meaningful. We want to test the bow and only the bow by ruling out all of the other factors that can skew or mask results.

Draw weight scales using springs can easily be off by one or two pounds. An accurate certified digital scale is crucial to making meaningful comparisons between bows.

Unless your weight scale is regularly checked against certified weights the data collected about bow performance may well be inaccurate.

Arrow weight scales are another potential source of error. Again, accurate digital scales that are frequently calibrated ensure accuracy.

The AMO specifies a standard for draw length measurement. That standard can be summarized as follows: for "AMO" draw length, the actual distance the bow is drawn is measured from the pivot point of the grip and then 1.75" is added. So a 28" AMO draw length is actually 26.25" from the pivot point of the grip to the arrow nock. A 30" AMO draw length is actually 28.25" from the pivot point of the grip to the arrow nock. Varying the draw length even ¼" will make a measurable difference in arrow speed. Exactly measuring draw length and doing so repeatedly is critical to evaluating bow performance accurately. Other than using a shooting machine we don't know of another way to achieve consistent draw lengths.

Much discussion about brace height occurs whenever two archers discuss how one bow performs versus another. And it is certainly true that varying brace height on any given bow will change arrow speed. On the Dryad ACS longbows and recurves we typically suggest a 1" range of brace heights. Based on our personal experience we've found that the "sweet spot" for that particular model bow usually lies within that range. All of our testing is done with the brace height set in the middle of that range. On our bows, varying brace height plus or minus ½" will change the arrow speed about 1.5 fps each way. Some bowyers say that their bows should be tested at extremely low brace heights – as low as 6" or even less. Those same bowyers shoot their own bows of that same model with brace heights over 8", so what does that tell us? Hmmmm. Bows should be tested at the brace height they are designed for – where they shoot their best. Put them in the mid-point of that "sweet-spot" range and test them there. That's what we do and we think it is a reasonable way to approach brace height selection. Otherwise bow performance comparisons are reduced in value and accuracy.

String weight also makes a difference in arrow speed. Much has been written about string materials and string designs. But based on our fairly extensive experience we've found that varying string weight by 20 grains makes about 1 fps difference in the speed from our ACS bows. We usually test our bows with 12-strand DF-97 flemish twist strings – the exact same string that we use to hunt with our bows. Again, we're interested in determining how the bow performs for the archer. On conventional bows with heavier limbs and with lower SE/PDF and DE numbers, changing string weight as much as 75 grains is necessary in order to make a difference of 1 fps. Sort of like putting an extra 1000 pounds on an 18-wheeler that already weighs 35,000 pounds. You won't notice it!

Nock fit can effect arrow speed measurements. If nocks fit too tightly on the string results can be skewed.

Test arrows should be shot without fletching. Interaction between fletching and the arrow rest, especially if the rest is something like Velcro or fur, can have a material impact on tested arrow speeds.

There are other variables that could be mentioned but these are the most important ones.

What's Different About Dryad Bows?

The simplest answer is that we care about this performance stuff. We have taken the time to study bow performance and what makes bows tick. We extensively test all of our designs and seek ways to improve them. A good example is the careful development invested into our new ACS recurve. Years of testing have gone into the current design.

It's fair to say that some bowyers get a design that shoots and that's when they drive a developmental peg into the ground. Production immediately follows. Frequently "new design changes" equal little if anything more than offering the same old design in a different kind of wood. Or perhaps they use a new laminate that offers marketing benefits but little if any performance benefits. Some bows on the market have designs that haven't been changed or improved in decades. That might be good for business, but how boring would that be? We'd rather get a root canal than market the same old stuff in new packaging.

When we at Dryad get a design that works and shoots we're just beginning. We want to know if we change this bit of geometry or lengthen that or shorten this or change the shape – what happens? How can we make it better? What additional optimization can we add to the design? What happens if we use a different laminate? What happens if we use a different core? This process often takes multiple years before we're satisfied. Only by changing one thing at a time and carefully testing the resulting bow's performance can a bowyer understand the impact of that change. It requires building new limb molds, making new limbs that incorporate only one change from the previous design, and then testing that prototype exhaustively to understand the impact of the most recent change. Learn from that one experiment and then decide what to change and try again. Repeat and repeat and repeat until the improvements are no longer material. Not easy, not quick, and arguably not intelligent from a business viewpoint - but it's the only way we know to optimize our designs.

After finally driving our own design peg into the ground we go one step further before production. We cycle test all of our new designs a minimum of 50,000 cycles in order to satisfy ourselves that our bow limbs will provide safety and performance. We don't have to do that – most bow manufacturers don't. Building a cycle tester is neither easy nor inexpensive. But it's the only way to know for sure if our products will meet our own high standards for durability and dependability.

The other guys might be better at marketing, and some might argue that they are the smarter businessmen. But at the risk of being too nerdy, we'd rather get it "right" before selling our bows. We think that you – the customer – will ultimately appreciate the thought and care and design sweat that goes into your Dryad ACS bows.

We will always be looking for the next best thing.

About Dryad Bows – The Company

Just a quick word about us here at Dryad and the bows we build. Mike, Connie, and Jason Westvang originally founded the company. Dryad has been growing every year, and through the years the Westvangs became friends with John Havard. John wrote the ACS Patent, paid for it, and owns all rights to it. Other companies may build ACS bows under license to John, but the Westvang family and John are all owners of Dryad Bows and will be using their partnership to fully exploit all of the potential applications for using ACS technology on a full line of bows. If you are interested in where the next innovations based on the ACS concept will come from, look no further.

We are offering a variety of ACS bow limbs. Matching performance levels with price levels will be a central theme in our product line. Even an entry-level bow limb can be made better with ACS. Our top of the line bows and limbs will make use of the very best in materials and ACS technology in order to maximize performance. Added performance requires more specialized materials and more time/effort to produce. Therefore bow limb cost will be closely linked to bow limb performance.

So it's possible to have a range of ACS bows, all of which benefit from our tireless attention to design improvements and understanding of what makes a bow perform. Generally there will be a spread of around 10 feet per second between our entry-level ACS bow limbs and our top performers. As the examples below will show, don't think that 10 fps is not material. It's basically the same as adding two more inches of draw length to your power stroke!

Summarizing Bow Performance

Okay. We've discussed the two main components which control bow performance: energy storage and dynamic efficiency. Now let's put together some real world examples and see how important bow performance really is:

Example # 1:

An archer shoots a straight-limb longbow. He draws 60# @ 28". He shoots a 750-grain arrow at 144 fps.

Question: What weight ACS hybrid longbow would shoot the same arrow the same speed?

Answer: An ACS CG longbow drawing 42# will shoot the same arrow the same speed.

How can that be? Let's start from the beginning. The archer's straight-limbed longbow shoots a 750-grain arrow at 144 fps because the SE/PDF of his bow is .78 (because of the heavy arrow) and the DE = .74. Both of these numbers can be found in the earlier tables. The calculation goes like this: First of all, a 750-grain arrow traveling 144 fps has 34.6 ft-lbs of energy. Given that an ACS hybrid longbow has a SE/PDF at 28" of .94 and a DE of .84 (at 9 gr/#), we can back calculate the draw weight required to shoot a 750-grain arrow 144 fps. The ACS longbow will have a dynamic efficiency of 88% given the very heavy arrow. So a 750-grain arrow with 34.6 ft-lbs of energy must be shot from an ACS that stores 34.6/.88 = 39.3 ft-lbs of energy. Knowing that the SE/PDF (at 28") for this particular bow is .94, we calculate that 39.3 ft-lbs divided by .94 (DE) yields a draw weight of 42#. Which can you shoot more accurately - 42# or 60#?

Example # 2:

An archer shoots a top-of-the-line recurve or hybrid longbow with conventional limbs. His bow pulls 60# @ 28". He shoots a 540 grain arrow 185 fps (40.9 ft-lbs of energy) with this setup.

Question: If he shoots the same draw weight and the same arrow from his new Dryad ACS CG longbow, how much more energy will the arrow have and how much faster will the arrow go?
Answer: A Dryad ACS CG longbow drawing 60# @ 28" will shoot the same 540 grain arrow at 199 fps versus 185 fps and the kinetic energy will increase by 16%.

Here's the math. Again, an ACS has a DE of .84 at 9 grains per pound and a SE/PDF of .94 at 28". First, it is simple to calculate the energy transmitted into an arrow from a 60# @ 28" ACS longbow. 60#*.94*.84 = 47.4 ft-lbs. Now putting 47.4 ft-lbs into the equation for kinetic energy and solving for arrow velocity we find that the 60# @ 28" ACS longbow will shoot the same arrow at the same draw weight 199 fps versus 185. This represents an increase in energy of 17% (47.4-40.9)/40.9 = 16%

Example # 3:

The same archer in the prior example doesn't want his arrow to go any faster. He likes having his 540-grain arrow fly at 185 fps.

Question: How much lower in draw weight could he go with a Dryad ACS CG longbow versus his top-of-the-line recurve and still shoot the same arrow the same speed?

Answer: He can drop down from 60# @ 28" to 52# @ 28" on his ACS longbow and shoot the same arrow the same speed.

Again, here's the math. We know from the previous example that his arrow kinetic energy is 40.95 ft-lbs. An ACS longbow has a dynamic efficiency of .84 at 9 grains per pound an a SE/PDF of .94 at 28". Solving gives us: 40.95/.84 = 48.75 ft-lbs of stored energy in the ACS. Now, dividing the stored energy by the SE/PDF yields 48.75/.94 = 52#. So the archer could take a 52# Dryad ACS CG longbow and match the performance of his 60# top-of-the-line recurve. I don't know about you, but I sure can shoot 52# more easily than 60#!

Example # 4:

One archer draws only 26" and his hunting buddy draws 28". The archer with the short draw wants the same amount of energy for elk hunting as his partner. His partner is using a top-of-the-line recurve that pulls 60# @ 28" and is shooting a 700 grain arrow at 181 fps. The archer with the shorter draw length wants his Dryad ACS CG longbow to have the same amount of energy as his friends recurve and he also wants to shoot a 700 grain arrow at the same speed of 181 fps.

Question: What draw weight will the archer with the 26" draw need from his Dryad ACS CG longbow in order to match the performance of his friend's 60# @ 28" top-end recurve?

Answer: The archer with the shorter 26" draw can shoot a Dryad ACS CG longbow with a draw weight of 56# @ 26" and match the performance of his friend with a 60# @ 28" draw shooting a top-end recurve.

The Math: The archer with the 28" draw is pulling 60#, so his arrow weighs 11.7 grains per pound of draw (gpp). Because of the heavier arrow the recurve has a DE of around 78% and therefore puts 42.6 ft-lbs into the 700 grain arrow (compared with 40.95 for the 540 grain arrow). This means that he shoots the 700 grain arrow at 181 fps. An ACS longbow has a dynamic efficiency of .84 at 9 grains per pound, or about .87 at about 12 grains per pound. The ACS has a SE/PDF at 26" of .87. The ACS owner wants to also shoot a 700 grain arrow at the same 181 fps, so by definition his ACS CG longbow must deliver the same 42.6 ft-lbs to the arrow. Solving for the necessary ACS draw weight at 26" yields: 42.6/.87 = 49.0 ft-lbs of stored energy. And given a SE/PDF of .87 we can calculate that the 26" draw ACS would need to pull 49.0/.88 = 56.3# @ 26" in order to equal his friend's top-of-the-line recurve drawing 60# @ 28". So an ACS drawing 56# @ 26" is equivalent to a top-of-the-line recurve drawing 60# @ 28". <u>By choosing a bow that performs well you can match the performance of many top-end bows at a shorter draw and at a lower draw weight</u>. Talk about leveling the playing field! That's what better performance is all about.

The examples given above reflect our actual experience testing ACS bows and other conventionally-built bows. Many more examples could be developed, but you get the picture. The first conclusion you can draw is that all bows are definitely not created equal. There are huge differences between the best and worst stickbows currently being used around the world. Which one you use is purely a matter of choice and personal preference. Just don't ever let anyone tell you there isn't any difference between bows and how they perform.

The Importance Of Arrow Speed

Critics of this pragmatic and objective definition of performance often say that 5 or 10 feet per second won't matter – it's unimportant and only a marketing gimmick.

Yet who would turn down the opportunity to shoot the same arrow the same speed with less draw weight? Or who would like to add 2" to their draw length?

In a carefully constructed test designed to maximize objectivity, a 5 feet per second difference in arrow speed is HUGE. Have you ever short-drawn your bow by 1"? Notice the difference in arrow trajectory? Well, short-drawing your bow 1" takes away right about 5 feet per second in arrow speed. What if you short-draw your bow 2" or 3"? What will your arrow trajectory be like?

Now let's turn that around. If you have a 26" draw length and want to equal the performance of your friend's 60# bow that he draws to 28" and you can do it AT YOUR SHORTER DRAW LENGTH AND WITH FEWER POUNDS OF DRAW, why would you turn that down?

This performance stuff is real. We believe in it and you will too as soon as you try it. Just don't ever let anyone try to tell you that a real 5 fps difference between bows is unimportant.