Question: How does the 2nd Law of Thermodynamics relate to the Energy Pyramid?

It relates by entropy, which is, most importantly, about the quality of the available energy.

(I believe this also answers several of the open questions.)

Entropy increases when the amount of **usable** energy decreases. It has also been described as the amount of chaos. A few examples are necessary.

1) When a ball (or any other object) is dropped, gravitational potential energy becomes kinetic energy (energy of motion). All of the molecules are roughly moving in the same direction: downward (very organized, low chaos). This energy is very useful because we could do work with it: have it move a lever to move another object or even move an electrical generator (like falling water hitting a waterwheel). When the ball hits the ground this energy converts into thermal energy (heat) of the floor, the ball, and the surrounding air. All of the energy is still there (1st Law of Thermodynamics or Conservation of Energy), but the ENTROPY has increased because the energy is less useful. We can't just recapture it to do work.

2) Imagine a close container full of air. In this configuration no work can be done because the molecules are not organized. But if we did work on the gas, we could push them to one side and capture them behind a barrier (like a wall). Even though the amount of gas and energy is still the same (though the pressure is higher), the amount of ENTROPY has decreased because we can do work with it. We could make a hole in the wall and the escaping gas could turn a generator, again. When the energy is USEFUL there is LOW entropy.

Now to the energy pyramid - As each level consumes organisms from the lower levels the creatures become more organized and the entropy goes down. However, each creature expels waste and heat, which are less useful. Therefore, as you go up the pyramid the entropy of the organism goes down, but the TOTAL ENTROPY of the world goes up, thus fulfilling the 2nd Law of Thermodynamics which says "In all natural processes the entropy must increase." (one paraphrase).

Hope it helps - cstephenmurray.com