Let's Look at Saving Electricity:

Light Production Efficiency &

Diminished Heat Generation

It's a simple mathematical exercise to compute the cost justification of LED lighting compared to legacy incandescent lighting. Or, is it?

If our answer is "yes", we're probably thinking… use subtraction to find the difference in energy consumption (watts) of the two devices, multiply that difference by the time the light is used and then multiply that product by the cost per watt per hour. For example, if I replace a 75 watt flood lamp with a 9 watt LED lamp, I will use 66 fewer watts of electrical energy while the light is illuminated. If I use it 12 hours per day, I will use 792 fewer watt hours per day. If I use it at that rate every day, I will use slightly more than 289,000 fewer watts hours per year. To make my last multiplication exercise more meaningful, I'll multiply 289 kilowatt hours times 11 cents per kilowatt hour (I get the price per kilowatt hour from my electrical bill), and find that my LED light will save me $31.80 per year in operating cost. If my cost for the lamp is about $50, I will pay for it in less than a year and a half. End of story! Or, is it?

It may be the end of the story if my application is outdoors, let's say using the lamp to light the entrance to an exterior door. But, what if I am using the lamp in a recessed ceiling fixture or a track application, in a meeting room or dining room? What if this is one of a number of identical lamps used for general ambient lighting? Then, to do an accurate cost analysis, I should also consider the change in ambient room temperature, and the resultant changes to the HVAC load. The math is just as straightforward as the math in our first case, just a little more complex. Let's start with the 66 watt difference in energy use in our before/after scenario. We have known for years that a little more than 90% of the electrical energy consumed by an incandescent bulb is used to generate heat; about 10% generates the useful light that we seek. LED lamps generate both heat and light, too, and even though LEDs are more energy efficient, let's multiply the 66 watts times 90% to compute the watts used to generate heat, 60 watts. Is there a way to convert watts of electricity used to generate heat into a useful expression of heat energy? There is! One continuous watt is equivalent to 3.41 BTUs per hour. So, a 60 watt hour equals 204.6 BTUs per hour. Employing the usage example above, if I replace my 75 watt flood lamp with a 9 watt LED, and use it 12 hours per day, 365 days per year, I will generate nearly 900,000 fewer BTUs of heat per year.

Here's where the cost justification gets more complicated. To know how much energy I consume by removing the added heat from my environment, I need to know how efficiently my air conditioning system can move the heat from indoors to outdoors. This can be computed *theoretically* at any given point in time by using something called a Coefficient of Performance (COP), which is a pure mathematical measurement of a given A/C system when it is running. However, A/C systems do not run continuously, and they are located in a variety of locations with differing outdoor temperature and humidity conditions. Therefore, the concepts of Energy Efficiency Ratio (EER) and Seasonal Energy Efficiency Ratio (SEER) have been developed. The EER of my A/C system is the ratio of output cooling in BTU/Hr to input electrical power in Watts at a given operating point (indoor and outdoor temperature and humidity conditions). Again, this is not a really useful value to extend across real variable conditions over a period of time, because of all the ambient differences in different physical locations. The Seasonal Energy Efficiency Ratio (SEER) was developed to overcome these limitations, in that it attempts to postulate an “average” that is somewhat applicable to many places in the US. Its units are BTU/Watt Hour, and instead of representing performance in a single static operating condition, it represents the expected overall performance for a typical year's weather in a given location. This approach is still not perfect, because a SEER 12 system running in August in Florida where the outdoor temp is 95 degrees will not move as many BTUs outdoors as the same model will move in April in New York City where it is 60 degrees.

We’ll work with the SEER rating, because that is the best measure currently available for a general and applicable discussion. Beginning in 2006, the US government mandated a minimum SEER of 13 for residential central air conditioners. Higher SEER air conditioning systems are available, but for our purposes, we need to consider the “real life” A/C systems that are actually out there and working. In order to generate a confident value for A/C required to remove heat generated by lighting, let’s postulate a reasonably average environment cooled by a SEER 12 system. This is a conservative scenario, as there are relatively few highly efficient systems in use, and there are many legacy systems that will be in use for many years. Our SEER 12 “example” system is approximately equivalent to a computed COP of about 2.92 which means that 2.92 units of heat energy are moved outdoors for each per unit of electrical energy used to run the unit. This approach will err on the conservative side (i.e. actual savings will exceed computed savings) for the typical system at this point in time. This is especially true for systems in warm climates.

Back to the math: What does it cost to move about 900,000 BTUs of heat to move outdoors? Using the ratio of 2.92:1, my A/C system will require the electrical energy equivalent of about 307,000 BTUs to move that heat. (896,148 divided by 2.92). Using the values discussed above, that works out to 90,000 watts per year of electrical energy required to remove that heat. (306,900 divided by 3.41) At 11 cents per kWh, that’s an additional $9.90 per year of cost difference between the incandescent and LED flood lamp, for a total annual cost difference of $ 41.70, or a payback on the lamp of 1.2 years. And remember, that is conservative, based on a very optimistic assumption of a 12 SEER environment. The more typical 9-10 SEER equipment, with age and maintenance degradation would result in heat load removal costs in excess of $15 per year, with total cost differential in excess of $47 per year. Older, inefficient systems will cost even more.