Introduction:

 In 2014 I started an Assistant Professor of Design position at Central College in Pella, IA. One of the main reasons I took the job was because of the school’s incredible dedication to Sustainability education. Having created a website[[1]](#footnote-1) dedicated to sustainable theatre, I was thrilled to be part of an academic community that shared my passion and vision. Shortly after being hired I was told by the Dean of Faculty, Dr. Mary Strey, that she wanted me to find a ways to incorporate sustainable practices into the Theatre Department. Having recently acquired a grant from the Margaret A. Cargill (M.A.G.) Foundation to develop and increase sustainability education at Central College, Administration and the President Mark Putnam, were actually looking for ways to incorporate sustainability in fields outside of the sciences (the sciences being the most “common area for sustainability integration).

 At first glance, Dr. Strey and I both thought the fastest way to incorporate sustainable practices into the Theatre Department would be through the replacement of all (or most) the old stage lighting fixtures to more energy efficient and perhaps LED ones. Not only would replacement help with energy inefficiency but it would also help address the educational impact of teaching lighting design with lights that have are not seen in contemporary theaters in 2015. When I taught Lighting Design my first semester I was used a textbook from 1994 as this was the only one that even referenced some of the fixtures we used regularly. How could I expect to prepare my students for internships, graduate school or even community theatre, when a majority of our instruments when not in regular circulation in the theatre field? On the other hand, I knew that a complete replacement of instruments would be impossible both finically and would not make sense on an academic front. Being a Liberal Arts program that awards students a “general” Theatre Arts B.A., having all the newest and best equipment would not serve the students either. Most would not be moving to Broadway or large regional theaters where the newest technology was more the norm.

 With the M.A.G. Foundation funding also came sponsored student/faculty sustainability research over the summer of 2015. This gave myself and my student researcher Brandie Heims (Junior year Biology Major, Theatre Minor) the opportunity to do an energy audit on the theater and find more sustainable replacements that would also adhere to our educational goals. Our objective was to find replacements that would: adhere to Central’s sustainability mission (from both an environmental and economical standpoint); Advance the academic and Liberal Arts missions of the school and the Theatre program; and still maintain the artistic norms that the students, the school and the faculty have grown accustom to regarding how they design and work in the space. My original idea was that Brandie and I would be able to easily compare old stage instruments we own with new instruments and find the best way we could buy and then spend a portion of the summer looking at other aspects of sustainability. It became clear very quickly that not only was the data hard to find on these older fixtures, but also that the stage instruments alone were only a small piece of the pie. After four weeks of hunting, calculating and spread-sheeting (and doing more math than any theatre person should have to) it became overwhelmingly clear that, for Central College Theatre Department’s purposes, the most effective change would be replacing combination of work lights, task lights, stage lights and rethinking the way we use the lights when we work. The changes that we proposed were the most sustainable (when including both economic and environmental aspects), adhere to the academic objectives of the school and the department, and the artistic traditions of the Department.

The Research Process:

 We started our research by doing an inventory of every light in the building and then every stage, house and work light[[2]](#footnote-2) (and lamp) in the main theatre. Though we have a studio space, the lights are rarely used and hang in a rep position so we decided that we would not include these lights in our inventory as the use of these would be so minimal that they would not effect the overall energy consumption enough to justify the cost of replacement. Once an inventory was done we were able to start the search for data on each of the lights.

 We learned that most of the stage instruments and house lights were purchased in 1984 when the building was constructed. With the exceptions of about twenty Source Fours, and a dozen Strand Lekos from the mid-1990s, our entre stage and house light inventory was Strand Century instruments from the early 1980’s. Though we were fortunate enough not to discover any asbestos cords, the old inventory as a whole was heavy, awkward and the lamps averaged 1000w[[3]](#footnote-3).

 While taking the inventory we tried to gather as much information as we could for each instrument in order to help us better locate the documentation online. This was easy for the Source Fours and the Strand Centurys (which made up almost 65% of our fixed focus ellipsoidals) as all the information was clearly labeled on the instrument and/or yoke. Others, like Iris 2’ cyc lights which only gave us the wattage max or the House lights, only displaying a faded sticker with the distributer’s name, were more worrisome. I was dreading the hours of digging through the web to find anything that could resemble a datasheet for the more obscure instruments. Luckily, early in my search, I found the website “The Strand Archive” (<http://www.strandarchive.co.uk/>) which, much like it sounds, is an online archive of old lighting equipment from Strand Electric. On top of the website being a treasure trove for lighting geeks, it provided me with every datasheet I needed for all the older instruments. The newer instruments were easily found on the manufactures websites.

 Once the data was found I thought the comparison between instruments would be easy since most data sheets have the same information no matter what instrument it was. What we soon discovered was that the newer instruments either had much more information on energy efficiency that the older ones did or made broad statements about efficiency in comparison to other lamps, not other instruments. We had to find a way to compare either heat dissipation or light distribution for every light of the same type and at the same throw distance in order to have a usable comparison. In other words, we knew that a Source Four 36˚ (S4 36˚) was more “efficient” than one of the Strand Century 6x9’s by just looking at the lumens per watt (lm/w) but could the same watt lamp light the same area with the same brightness from the same throw distance? This is where we got stuck, not just because of the lack of comparable data between the photometry sheets that spanned 30 years, but also because we could not find an way to calculate the loss of heat in relation to the amount of light. We spent days trying to compare the footcandles at various throw distances between instruments and lamps to come up with some sort of efficiency percentage that matched an efficiency rating on the Source Four 36˚ datasheet; but to no avail. Eventually, after calling every lighting designer I knew (none of which had an answer) I cornered a colleague Alexy Pronin in the Physics Department at Central who suggested we look at the amount of energy (watts) being used per second and compare it to the about of light (lumens) coming out per second. We realized that we were spending so much time worrying about finding an equation that worked in space (area lighted at a certain throw distance), we had disregarded an equation that existed in time (how much light being expelled in a specific unit of time). This ended up being the key.

 We used the variable *H*v [[4]](#footnote-4) (light emitted on a fixed area per second) and divided it by *H*e [[5]](#footnote-5) (energy emitted in a fixed area per second) to come up with a ratio that would compare the amount of light to the amount of energy at the same throw distance, thereby using both space and time to come up with the solution. Though this still did not give us the amount of heat loss for every instrument, it did give us a way to compare the rate of light and energy of the same type of instrument (for instance a 6x9 and a S4 36˚) regardless of different photometry data given for the individual instrument[[6]](#footnote-6). The information you need for the equation is the lumens, wattage and the lux (or the candela/footcandles) all of which could be found on every datasheet we had. This ratio came in handy later when looking at replacements for our older instruments as we had a way of comparing each instrument regardless of age, photometry data and lamp wattage.

 After the finding the inventory data we framed every set of lights (house, work, task and stage lights) with two questions: “What do the lights do?” and, “How do we use the lights?”. Through this framework we were able to research different ways of using lights as well as replacements that would fit our particular theatre space. “What do the lights do ?” was easy, and should transcend beyond our particular theatre space and culture so we could generalize that this might be the same for most theater spaces. For instance, we use the 6x9s as focused stage lights almost exclusively for performance situations therefore making their purpose: to light the stage. In the same vein, the task lights illuminate the hallway or the makeup ally, and the house lights are used for the audience portions of the theater. These will probably remain constant for any performance space or academic setting. The difference came in thinking about the question: “How do we use the lights?”. The answers not only stray away from the instrument’s original purpose (in some cases), but can could be different for every performance space an instrument is used in.

 To answer the “How” question, we broke up the lights into different categories; house lights, work lights, stage lights and task lights. This abled us to look at each component of our theater separately and understand how the lighting instruments needed to work for Central College Theatre Department specifically. For instance, we do use the 6x9s as there original function dictates: to illuminate the stage with a focused light. The house lights, on the other hand, are used to light the audience portions of the theater during performance but are also used every day as work and rehearsal lights since we to build the sets and rehearse in our performance space. This means that the “house lights” in our theatre serve multiple purposes beyond their traditional function. Our actual work lights are used for working in the catwalks that surround and hang above our main stage space. This means that on a normal day *our* work lights are never turned on even though they consume the least amount of energy than any other category of light in the theater[[7]](#footnote-7).

 Understanding the way we use the “house lights” thereby changes the way we look at the whole system and the interconnectedness of the categories previously assigned. We had to rearrange our perspective from the original category definitions to make sense with our system: Lights for performance (stage lights), Lights for the audience (house lights), lights for work in the catwalks, onstage, and in rehearsal (work lights) and lights used in the shops, hallways and Makeup Ally[[8]](#footnote-8) (task lights). These new definitions not only helped us in our assessment of the department’s sustainability but also in the research for replacements.

 Now that the categories were correct, we had to look at each of the systems in terms of energy, color, amount of light produced and the number of instruments we had (or should have). The energy, light, and number of instruments were already assessed from the previously mentioned data inventory. We also recorded the color temperature of all the lights during the original inventory but now had to compare them within their assigned categories for effectiveness and continuity. For instance, we asked ourselves, is the color temperature of the work lights similar to that of the stage lights so scenic painting would not be negatively affected? The same question should now be asked of the task lights, especially in Makeup Ally. Along with color, we also questioned whether the amount of light being produced was appropriate for the light’s function. The amount of light produced from the stage lights was proven appropriate from 30 years of production but were our work lights giving off enough light to enable safe and effective working conditions? These questions could not be answered through any equation, but only through a true retrospective of how we use the lights in the different categories.

 Finally, we asked these same questions and utilized the data assessment tools we had collected, to research a variety of new and different instruments from several lighting companies. We analyzed and researched replacements for each category (Work, Task, Stage and House) and tried numerous combinations of stage and home LEDs instruments, stage Tungsten/Halogen Instruments, and Architectural lighting systems all using the *H*v */H*e ratio and lumen/watt comparison. This gave us a good idea of whether the replacements would be appropriately comparable (in terms of actual light emitted) to our inventory instruments. Once the most similar replacements were found we could than take the data from them and compare lumens/watt, Kwh output, Co2 emissions, and cost (per Kwh) for these and our inventory instruments. All data was measured in terms of 1 hour increments with the instruments being at 100%. Though we knew that we would never have every instrument in our inventory on at 100% ever, this gave us a broad scope of energy comparison without looking at individual designs and production. For the House, Work and task lights, we were able to also do a measurement of an average day use since we knew (over the course of 365 days) approximately how often our work, house and task lights were on[[9]](#footnote-9). Because these lights *are* usually on at 100%, we could get a more specific cost and energy assessment for these categories.

Results:

Conclusion:

1. [www.the-g-room.com](http://www.the-g-room.com) funded by The Puffin Foundation [↑](#footnote-ref-1)
2. See Appendix A [↑](#footnote-ref-2)
3. This average does not include the newer Strand Leko’s and Source Fours [↑](#footnote-ref-3)
4. *H*v = *E*v t or *H*v =Lumens/meters squared (or lux), times seconds [↑](#footnote-ref-4)
5. *H*e =Eet or *H*e =watts/meters squared, times seconds. Square meters were the same as calculated in the lux. Ee was determined using the equation: Ee=*E*v(lx)×*A*(m2) /*η*(lm/W) [↑](#footnote-ref-5)
6. When calculating from the photometry data we kept the throw distances as similar as possible. For the Century/Source 4 comparison we used a throw distance of 60’. [↑](#footnote-ref-6)
7. Our work lights on the catwalks were made up of 72, 18w and 20w compact florescent bulbs. [↑](#footnote-ref-7)
8. The term “Makeup Ally” refers to two banks of makeup stations located backstage and outside of the dressing rooms. This area is used for performance, rehearsal and also when teaching Makeup classes. [↑](#footnote-ref-8)
9. We averaged out work (house) lights at 5.7 hours per day, our catwalk work lights 2.9 hours per day and our task light (specifically the Makeup Alley) .25 hours per day over the course of an entire year. This factors in that most of these lights are not used during schools breaks and, other than the work (house) lights, are not used outside of production. [↑](#footnote-ref-9)